WATER MANAGEMENT IN THE SOUTH AFRICAN MINING SECTOR: THE ROLE OF CLIMATE STRESS

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DECLARATION

I declare that this research report is my own unaided work. It is submitted for the degree of Master of Science in Environmental Science: Interdisciplinary Global Change Studies in the School of Animal, Plant and Environmental Studies, Faculty of Science University of the Witwatersrand, Johannesburg. It has not been submitted before for any other degree or examination at any other University.

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Marie Lugalya

Signed at 20th February 2017

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List of Abbreviations

AWM	Adaptive Water Management
CDP	Carbon Disclosure Project
BPGs	Best Practice Guidelines
DEA	Department of Environmental Affairs
DMR	Department of Mineral Resources
DST	Department of Science and Technology
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
ICMM	International Council on Mining and Metals
IPCC	Intergovernmental Panel on Climate Change
NBI	National Business Initiative
NWA	National Water Act, 1998 (Act 36 of 1998)
NWRS	National Water Resource Strategy
WC/WDM	Water Conservation and Water Demand Management
WRC	Water Research Commission
WSA	Water Services Authority
WUA	Water Users' Association

Chapter 1: Introduction

1.1 Background

Water including both abundance and scarcity are critical issues worldwide. Concerns are escalating across the globe as many nations are struggling to secure sufficient water (CDP, 2013). Water shortages and periods of abundance could be triggered by several factors either due to physical conditions (rainfall patterns, evaporation, and temperature) or management capacities (policies, regulation, maintenance and monitoring) (Faramarzi *et al.,* 2013). Furthermore the rate at which environmental, social, economic and political systems are continuously shifting has further complicated this issue. Factors, such as overpopulation, inadequate governance, rapid industrial development, intensive agricultural farming and extreme weather conditions all have the potential to adversely influence existing water scarcity (Faramarzi *et al.,* 2013).

Similar to many developing countries, South Africa faces the predicament of sustaining growing populations and industrial developments whilst preserving the ecosystem (DEA, 2013). The country is particularly vulnerable to periods of excess and water scarcity due to its distinctive climatic conditions. South Africa is characterised by exceedingly variable to low rainfall patterns, decreased humidity and high air temperatures (Ziervogel *et al.,* 2014). The combination of these climatic conditions causes high levels of evaporation resulting in reduced water availability (Ziervogel *et al.,* 2014).

Climate alone does not influence water supply, as water conditions are impeded by various socioeconomic challenges. The severity of water scarcity, for example, is further compounded by rising water demands and declining water quality within the country (DEA, 2013). Water is essential for several processes across various industries (including health care, pharmaceuticals, energy, retail, construction agriculture, manufacturing, food and beverages) all of which contribute towards a thriving economy (DEA, 2013). Therefore the impacts of water scarcity and abundance (for example, extreme flooding) could likely threaten all water-dependent industries, the consequence of which would be devastating throughout the country.

1.2 Importance of water in the mining industry

Water is one of the most valuable natural resources, particularly in the mining sector, as the majority of mining processes rely heavily on water (CDP, 2014). Water plays a critical role through all stages from exploration, construction and establishment of the mine to operation, decommissioning and mine closure (ICMM, 2012). Water is commonly used in mineral processing, power generation, dust suppression, cooling of machinery, slurry transport and waste management. Other uses of water include drinking and sanitation provisions for employees. Additionally water availability is crucial in terms of effectively conserving and rehabilitating mining sites (ICMM, 2015). Bearing in mind that the life cycle of mining projects in South Africa are typically 10-50 years, securing water might become problematic in the long run (CDP, 2013). Subsequently water scarcity could severely impact the South African mining industry.

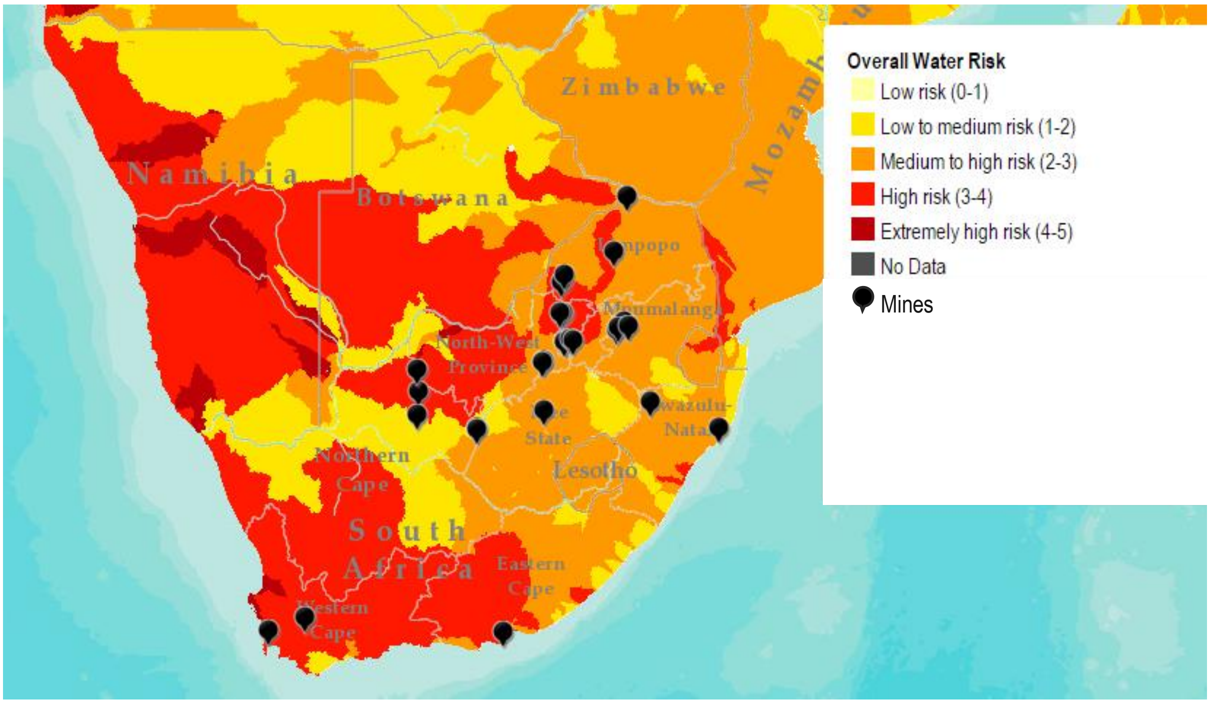

Figure 1: South African mines and water risk areas. Source: WRI Aqueduct 2014.

The variation of water availability in South Africa has raised many concerns across the industry (CDP, 2014). As shown in Figure 1, there is a high proportion of mines situated in zones with medium to high or high water risks. These mines are mainly in the North West, Limpopo, Mpumalanga, Gauteng and Western Cape provinces. According to the WRI Aqueduct (2014), these regions are experiencing physical risks associated with water for instance water quantity and quality, baseline water availability, water withdrawals, storage capacity, seasonal and inter-annual water variability. Other water risks include drought and flood occurrence as well as access to water in these areas. In order to counteract these water risks, mining companies have incorporated recycling methods and multiple water abstraction methods. Although the bulk of water abstracted is from ground and surface water, the rest is sourced from potable water, externally sourced non-potable water, wastewater, recycled and treated mine water.

1.1.2 Water projections according to climate variability

Climate variability has the potential to affect long-term and short-term abundance of water resources (Schulze, 2011). Long-term climate adaptation studies have indicated that water availability will vary remarkably across the country (DEA, 2013). The frequency and magnitude of available water is estimated to fluctuate throughout different regions. This could result in parts (for example, portions of the eastern regions) of the country facing excessive precipitation whilst other areas withstand severely low rainfall (south-west, central-western and northern regions) (DEA, 2013). Other potential risks include changes in annual hydrological patterns, humidity, temperature levels and wind intensity (DEA, 2013). Water dependent sectors, such as the mining industry may be more vulnerable to the impacts associated with too much or too little water supply.

1.2.2 Potential impact on the mining industry

According to the long-term climate adaptation projections, extensive rainfall will occur notably to the east of the country resulting in potential flooding (DEA, 2013). Many of these possible climate change impacts appear to be long-term, with scenarios embracing the period 2040-2050 (DEA, 2013). The impacts to mining operations would be widespread either direct, indirect or cumulative impacts depending on the distribution of mining operations in the area and the nature of surroundings; whether protected areas, residential, industrial or agricultural land. These impacts could range from destruction of tailing storage facilities or excessive tailings surface runoff into adjacent streams or dams (Fourie, 2009). Extensive rainfall could also result in flooding of open cast pits and underground mines which could cease operations for prolonged periods (Loechel *et al.,* 2013). Moreover, flooding could contribute to augmented decanting of underground pits causing acid mine drainage (Anawar, 2013; ICMM, 2013).

The South African Long-Term Adaptation Scenarios (LTAS) have also projected variability in the rate and extent of drought occurrence. Episodes of drought, in some cases enhanced by climate variability, are projected to be characterised by severe water scarcity in some areas (DEA, 2013). As a result there would be considerably less water available for waste and dust management as well as mineral processes and slurry transportation. (Loechel *et al.,* 2013). Similar to flooding, drought presents significant challenges in terms of rehabilitating and sustaining ecosystem functions for example, the rehabilitation of soil and vegetation cover would be problematic (ICMM, 2013).

The mining sector could also experience significant financial impacts globally and locally. These could be triggered due to delays as well as costly repairs and maintenance of machinery, infrastructure and emergency services. Likewise, in some cases, companies might need to invest in transport infrastructure such as constructing new roads in remote areas, with no financial assistance from governing bodies (CDP, 2013). The health and safety of personnel may also be impacted when operating under extreme climate conditions, e.g. heat waves caused by extremely variable temperatures or a greater incidence of water borne diseases (ICMM, 2013).

Other than climate-related factors there are numerous ways in which water can affect mining operations and their ability to generate profitable returns. In South Africa the process of acquiring a water use licence is problematic as national authorisations are more rigorous, as such, regulators are becoming more stringent in issuing water use licences due to the rise in water scarcity. Furthermore, water prices could potentially increase due to the reduction in water quality and availability (CDP, 2013).

Moreover, increased competition for water in the form of mass industrialisation and rapidly growing populations have also led to decreased water quality and availability resulting in increased mine operating costs (ICMM, 2013). There is also the added risk of struggling to obtain a social licence to operate due to communities refusing to share limited water resources (ICMM, 2013). Therefore under normal conditions the industry is already experiencing reputational, financial, physical and regulatory risks associated with water (CDP, 2013). Through extensive consideration of all these potential impacts, it is clear that adaptive planning is crucial to deal with water risks and the threats associated with climate variability and change.

1.3 Aim and objectives

This research aims to examine and document how 5 South African mining companies are planning to manage water risks, if at all, for periods of climate variability and change in their mining operations.

1.4 Key research questions

- How are South African mining companies currently dealing with climate risk in their management of water?
- Do South African mining companies have any future climate change adaptation plans for water management?
- Is it a national imperative to adaptively manage water in the extractive industry sector?
- Are there any barriers and opportunities that may constrain or facilitate effective climate change adaptation in the management of water?

1.5 Conclusion

Climate-related water issues are prominent in South Africa. As indicated above some parts of the country could potentially experience fluctuations in water availability, many of which are in prime mining regions. The South African mining industry faces the challenge of dealing with current water issues whilst preparing for future climate-related water issues. The following chapter will examine the various factors that influence water management in relation to climate variability across the South African mining landscape.

Chapter 2: Literature Review

The purpose of this chapter is to review the current knowledge of water in mining. This includes exploring: the challenges associated with water availability and quality under normal conditions as well as the impacts of climate stress on water systems within the mining sector. Therefore expanding on how these collective factors influence water management in the mining sector, ultimately highlighting the necessity to adapt to climate risks.

2.1 Water issues in mining

Water issues vary throughout the industry based on factors such as the type of ore that is mined, mining processes, climatic conditions, and the management practices from corporate through to site level (Miranda and Sauer, 2010). Many water concerns, however, are typically divided into water quality or availability considerations.

2.1.1 Water Quantity

Although the use of water in mining is similar to other industrial sectors, there are notable differences. For instance many global mining operations are located in under-developed regions, as such several mines typically supply themselves with water either through ground water or surface water i.e. oceans, rivers and dams (Prosser, *et al.,* 2011). Establishing a secure water supply is a lengthy process characterised by site exploration, water feasibility studies, meeting legal requirements, water licence applications, and renewals (ICMM, 2012). Other procedures include constructing and maintaining water infrastructure (pumping, purification and storing facilities), adhering to water withdrawal and discharge limits, management of mine water, and in some cases supplying communities with water as well (ICMM, 2012). Across the globe, mining operations are generally confronted with either abundant or scarce water supply (ICMM, 2012). In South Africa, however, many rich mineral deposits are situated in water-stressed regions, therefore several mines are vulnerable to water shortages. Moreover the average life cycle of mining projects in the country is approximately 10-50 years, and so establishing long-term water supply is problematic (Anglo American, 2013).

According to the 2015 CDP water report, water security was a major threat in the mining industry world-wide. Mining operations in developing countries are particularly susceptible because the severity of water scarcity, is further exacerbated by rising water demands from competing industries, domestic use, as well as declining water quality within those countries. Emerging economies such as India and China are developing at a faster rate than ever before. For instance the Chinese mining sector has become a powerhouse destabilising global commodity markets. The outcome of which has been a decline in commodity prices within competing countries (Miranda and Sauer, 2010). That said, the alarming rate at which economies such as China and India are emerging may potentially widen the gap between the amount of freshwater readily available and the amount required to drive vital agricultural, industrial, domestic and mining activities in other parts of the world (Miranda and Sauer, 2010).

2.1.2 Water quality

The quality of water is a longstanding issue in mining. During the extraction and processing stages, a significant amount of waste is produced (Aubertin and Bussiere, 2001). The waste produced is stored in tailing facilities, as such tailing structures are considered to be the most predominant source of pollution in mining (Schwarz *et al.,* 2009). The core challenges emerge when water comes into contact with various mine waste and surfaces (Schwarz *et al.,* 2009). The type and extent of water contamination varies based on the origin of the contaminant such as: waste rock, ore stockpiles, pit walls, tailings impoundments and pipes as well as abandoned pits (Adler *et al.,* 2007; Schwarz *et al.,* 2009; Mulligan *et al.,* 2011).

Uranium is one contaminant in particular that has plagued the mining industry as well as surrounding communities (Liefferink, 2015). Uranium is a heavy metal commonly encountered in gold mining characterised as chemotoxic and radioactive (Winde, 2009). South Africa's long history of gold mining from 1886 has resulted in approximately 800 000 tons of uranium mined. Up until 2002 roughly 25% of this uranium had been extracted and sold, the remainder of which was stored in tailings facilities (Winde, 2009). These storage structures remained neglected for a long period of time, causing major issues such as ground water leaching, acid mine drainage, surface water runoff, and dam failure (Winde, 2013). Other challenges associated with tailing structures includes wind erosion. Wind is occurs during the dry season, primarily in the winter months. This excessive wind blows layers of tailing dust into nearby water bodies (dams, rivers, and storm water drainage systems) as well as neighbouring communities resulting is detrimental health impacts (Liefferink, 2015;

Winde, 2013). For instance in the Witwatersrand, the exposure of tailing structures to urban residents is vast with approximately 270 tailing dams in a 400km^2 area (Liefferink, 2010). These tailing dams tend to lack all forms of rehabilitative (i.e. vegetation cover that prevents surface water runoff and dust) or preventative measure (i.e. lining that prevents seepage of toxins into the ground water) (Liefferink, 2010). According to Ochieng and others (2010), mine contaminated water is a critical issue affecting South African freshwater resources. They further explain that mine water containing suspended solids and heavy metals deteriorates the quality of surrounding water sources.

Usually water is used as a medium to convey and store waste products as it reduces the extent of dust pollution. The main drawback, however, is when water structures (ponds, dams and tailing facilities) fail and spillages occur. Incidents where tailings burst or leak have had detrimental environmental, health and safety impacts on nearby communities (Moreno and Neretnieks, 2006; Liefferink, 2007; Azam and Li, 2010; Zheng *et al.,* 2011). The consequences of poor water quality would have sizeable social impacts, impairing human health, reducing crop yields, and causing a high incidence of fish and cattle death in the surrounding areas (Fourie 2009). These detrimental impacts tend to be followed by large fines, substantial remediation and rehabilitation costs and major losses in reputational and shareholder value, therefore mining houses should aim to reduce incidents as much as possible (Fourie 2009).

Table 1: Water-related challenges at various mining stages.

Stage	Potential challenges
Exploration and mine construction	• Surface water contamination due to fuel and chemical spills as well as increased sediment residue
Mineral extraction	• Water contamination (both surface and ground) from chemicals and toxins • Landscape transformations (shafts, stream morphology, tailing dumps and pits) • Increased erosion and siltation • High water consumption • Groundwater depletion
Processing	• Water contamination (both surface and ground) from chemicals and toxins • High water consumption
Product transport	• High water consumption
Mine-closure /post-operation	• Water contamination (both surface and ground) from chemicals and toxins • High rehabilitation cost (treating contaminated water and soil) • Long-lasting landscape transformations (shafts, stream morphology and tailing dumps)

Source: Adapted from (Miranda and Sauer, 2010). Mine the gap : connecting water risks and disclosure in the mining sector. pp. 2.

As shown in Table 1, water related issues can occur across each stage of the mine cycle. Furthermore mining operations could change the hydrological and topographical features of the surrounding area, adversely affecting the soil moisture, soil and water toxicity, surface and groundwater flow as well as evapotranspiration patterns (DWAF, 2008).

It is evident that under normal conditions water is essential to mining processes and can have detrimental impacts to the surrounding environment and community. As such the mining industry could be vulnerable to the impacts of climate variability especially in matters concerning water availability and quality (Loechel *et al.,* 2013).

2.2 Climate variability

Having described the background to water-related issues in mining, attention now turns to describing climate variability and the implications on local mining. In this report, climate variability refers to any changes in climate patterns and conditions over periods of time, including changes induced both naturally and through human activity (Füssel, 2012). In brief the hydrological cycle is as follows: once on the surface, rain water flows into nearby water bodies such as rivers, dams and streams, some water seeps into the soil (Füssel, 2012). The water that seeps into the soil is usually absorbed by plants and transpired, whilst the rest of the soil water recharges groundwater reservoirs (Füssel, 2012).

There has been an exponential rise in water demand globally, including South Africa. Internationally, this rise has been linked to the underlying forces such as: population growth, rapid urbanisation, industrial development and improved standards of living (Miranda and Sauer, 2010). Studies suggest that climate variability will substantially alter the environment, thereby worsening pre-existing water challenges (DEA, 2013). These conditions include high temperatures, rainfall variability (i.e. severe droughts and flooding), and varying rainfall seasonality (Ford *et al.,* 2010; Nelson and Schuchard, 2011; Loechel *et al.,* 2013). The geographical distribution of these conditions will vary, many resulting in significant disruptions to water dependant industries such as the mining sector. Furthermore, growing scientific evidence indicates that rising air, surface and ocean temperatures will have long-term effects on the climate as well as weather conditions (Ford *et al.,* 2010; Nelson and Schuchard, 2011; Loechel *et al.,* 2013).

Upon surveying academic literature, it is clear that changes in temperature and rainfall will likely affect each of the processes in the hydrological cycle globally (Schulze, 2011; Cosgrove, 2013; Kusangaya *et al.,* 2014). For instance warmer temperatures may lead to a higher rate of evapotranspiration causing increased precipitation (Schulze 2011). In South Africa, whilst rainfall is projected to increase in some areas (eastern regions), studies also estimate that drier regions (south-west, central-western and northern regions) will experience substantially decreased precipitation levels (DEA, 2013). Schulze (2011), highlights that in some areas annual precipitation might not change, however, seasonal shifts in rainfall patterns may lead to water shortages due to precipitation levels rising in the wet season followed by a sharp decline in the dry season (Schulze, 2011; Kusangaya *et al.,* 2014). Extended periods of water scarcity may likely occur due to the combination of varying seasonal changes and increased temperature. Therefore higher temperatures will ultimately result in greater water demands irrespective of whether the water supply remains the same (Schulze, 2011; Kusangaya *et al.,* 2014).

The scientific evidence highlighting climate variability is extensive, scoping not only the causes and projected changes but the current and future implications of climate variability as well. Loechel *et al.,* (2013), stress that the implications associated with climate variability could be severely detrimental globally, affecting social development, economic viability and environmental conservation. They further emphasise that economies within each nation including individual sectors and regions need to identify and analyse potential climate variability risks.

Economies are particularly vulnerable to climate variability, especially primary economic activities or sectors that are predominantly reliant on natural resources (Ford *et al.,* 2010). The South African economy similar to other developing countries is fuelled by primary economic activities (Marais 2011). Sectors such as agriculture and mining have traditionally dominated the country's economy on a national and regional scale. For instance the mining sector is often a source of economic activity in the form of jobs on a regional level (i.e. corporate offices) and within local communities (i.e. operation sites). Therefore the potential climate vulnerability of South African mining activities has extensive economic and social consequences (Ford *et al.,* 2010).

2.3 Climate variability and mining

Presently many mining operations are experiencing harsh conditions associated with a variable climate (CDP, 2015). Changes in temperature, for example, increases the costs to cool down underground mine shafts (Mason *et al.,* 2013). High temperatures also increases surface water evaporation subsequently leading to excessive dust (Mason *et al.,*2013). As shown in Table 2, many climate-related issues are either directly or indirectly linked to water and how it is managed. Therefore adapting to climate variability is critical to managing water resources in the mining industry. Since several global mining operations are situated in harsh environments, many of them have extensive experience when it comes to managing short-term weather conditions.

Table 2: Summary of climate-related issues in mining globally.

Issues	Potential implications
Disturbance to mine structure and operations	• Damage to infrastructure from flooding and drought • Increased operation costs (e.g. due to mine dewatering or dust suppression) • Delay in meeting operation targets • Mine shutdown due to safety reasons
Disturbance to supply chains and distribution routes	• Disrupted transportation routes i.e. functional roads or ports • Limited access to supplies, services and facilities
Challenges to environmental management and mitigation	• Rehabilitation strategies might no longer be suitable due to altered environment (i.e. drought or flooding) • Difficulty revegetating mine sites • Increased water and soil treatment costs
Compromised community relations	• Increased competition for water resources with host community • Declined conditions may lead to civil unrest • Compromised social licence

Source: adapted from (Nelson and Schuchard, 2011). pp. 2-5.

According to the 2014 CDP report for South Africa, there has been a growing awareness of risks and opportunities of climate variability in the country. As shown in Figure 2, the South African mining sector (grouped here as energy and materials) is reporting more on climate-related water risks compared to other sectors. Mining companies with operations all over the country, highlighted climate change followed by increased water stress and flooding, as some of the major water risks. The most commonly disclosed impacts of climate risks, remain the same from 2011-2015. These Include: increased operational cost, reduced demand for goods/services and reduction/disruption in production capacity. The risks illustrated in Figure 2, are the same as those identified in this study. As for the future, research suggests that the extent of climate variability will likely become more adverse (Ford *et al.,* 2010; Nelson and Schuchard, 2011; Loechel *et al.,* 2013). Therefore studies stress that greater effort has to be placed on being as prepared when confronted long-term climate variability (Ford *et al.,* 2010; Nelson and Schuchard, 2011; Loechel *et al.,* 2013).

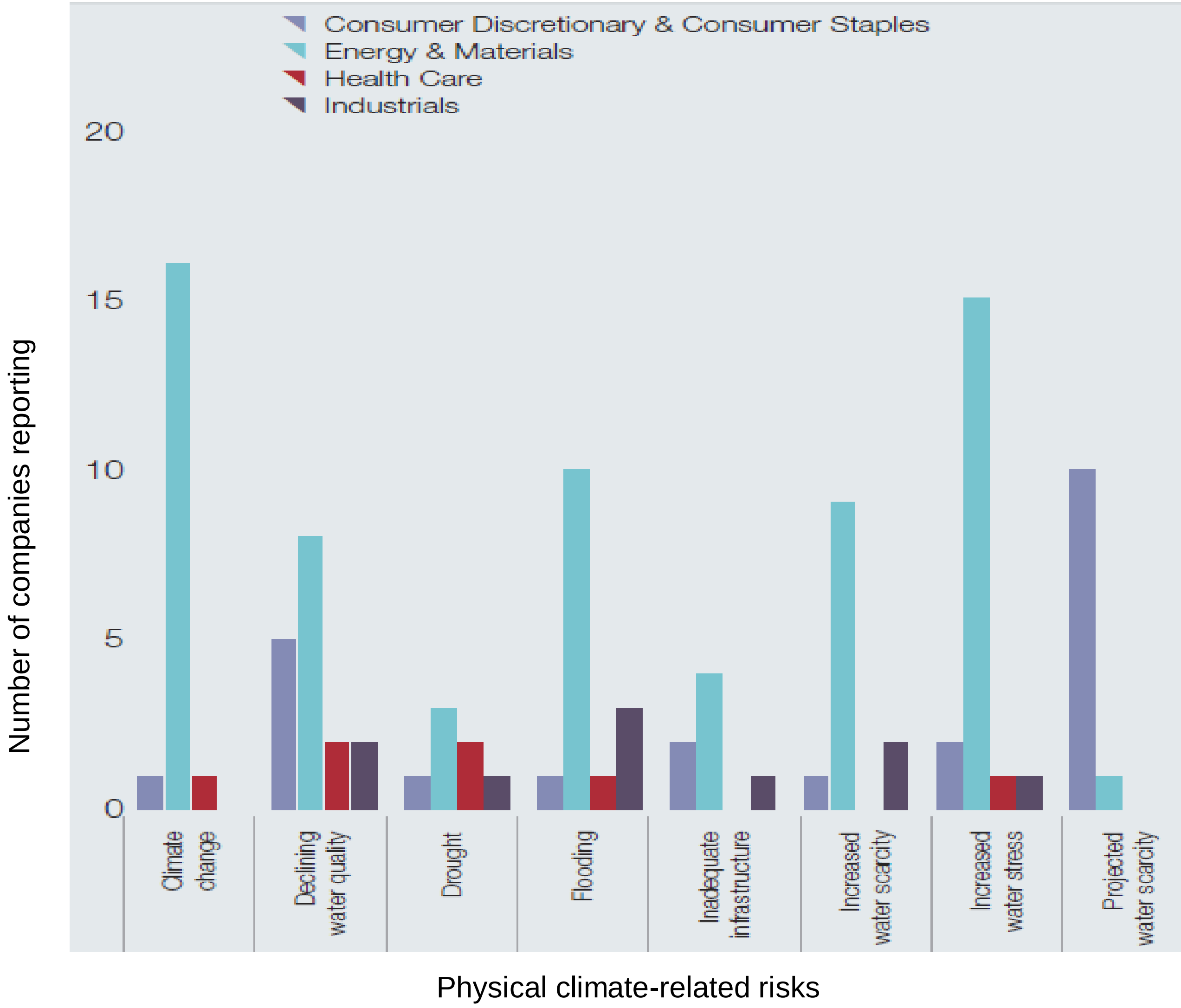

Figure 2: Physical risks linked to water in each sector. Source (CDP, 2014) pp. 20.

2.4 The management of water in mining

Water management is characterised by significant uncertainty, as such, the responses are typically risk-based with the aim of reducing the probability of detrimental outcomes or enhancing opportunities (Acuña and Peñailillo, 2014). Despite the threat of climate variability prompting awareness within the industry, mining professionals often wonder, why sustaining proactive management of climate-related water risks is regularly met with such difficulty (Acuña and Peñailillo, 2014). A particular concept provides some clarity on this predicament. The Hydro-illogical cycle explains how immediate climate-related water risks, commonly diverts attention from impending risks (Acuña and Peñailillo, 2014). Figure 3 illustrates an example of a time period where conditions are normal with typical rainfall patterns. During this time period the approach to water management is apathetic, hence, it is suggested that water may not be amongst the key priorities. Following this time period, as precipitation gradually decreases management teams become more aware of the limited water supply (Mine 2014). As conditions worsen, concern begins to set it. At this stage it is clear that the operation is in a vulnerable position. Ultimately the reality of facing an oncoming crisis triggers widespread panic resulting in a response that tends to be a rushed short-term based solution (Mine 2014).

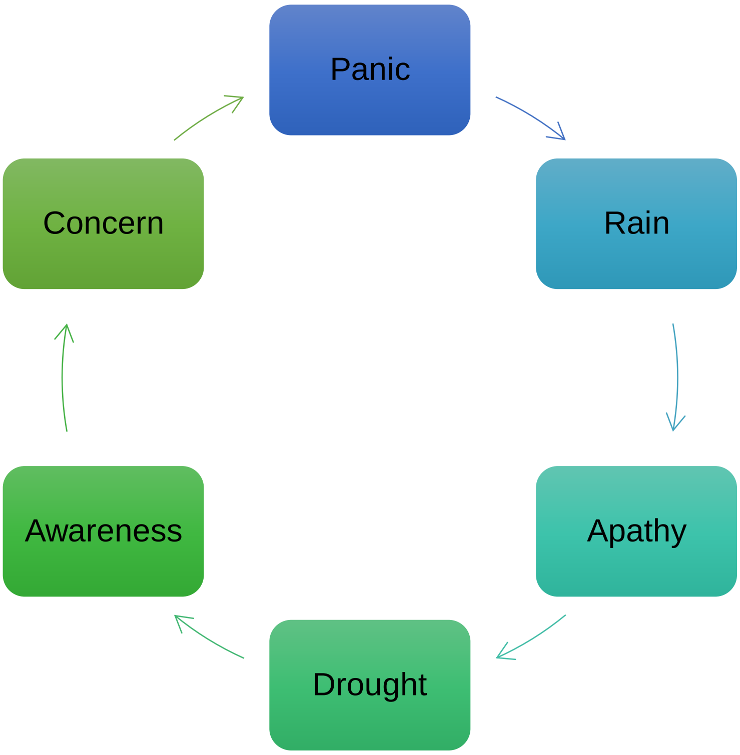

Figure 3: The Hydro-illogical cycle Adapted from (Rio Tinto, 2009).

A reactive as oppose to a proactive response is often identified within the industry (Mine 2014). Given the pressing issues associated with current threats (e.g. excessive rainfall) it makes sense to concentrate all efforts on dealing with these threats. The problem with this approach is that whilst efforts are concentrated on one particular issue, resources get diverted away from imminent threats. Hence perpetuating the cycle of urgently solving one problem after the next. Climate-related issues will vary thus requiring continuous adaptation (Jones and, Pittock 2002).

2.4.1 Adaptive Management

Adaptive management (AM) is an approach that spans several decades (Schreiber et al. 2004). The origin of the theories underpinning this form of management is estimated to be in the 1950 where researchers, Beverton and Holt explained the applications of adaptive decision making in the management of fisheries (Schreiber et al. 2004). Years later Holling (1978), and Walters and Hilborn (1978), developed a conceptual framework under the title of adaptive management (Schreiber et al. 2004). Walters (1986) further expanded the concept by adding technical aspects. This was followed by the publication of a book by Lee (1993), which enhanced the framework by explaining the social and political features that encompass adaptive management. Other definitions of adaptive management have been presented, one of which described AM as modifiable decision making based on uncertain outcomes (Schreiber et al. 2004).

Williams (2011), states that the need for adaptive management stems from the lack of certainty in natural resource systems. He further explains that it is imperative to document natural conditions due to the limited understanding of natural resource systems, therefore emphasising continuous learning whilst simultaneously managing natural resources. According to Williams (2011), the learning process emerges from the adjustments and informed decision making involved in the application of adaptive management. Responding to the risks and the impacts of climate variability requires measures to increase the capacity to adapt to the impacts that occur both short term and long term measures. Adaptation may be incremental or transformational, and it is often the outcome of efforts to enhance resilience (Williams, 2011).

2.4.2 Coping vs. adapting

Smith *et al.,* (2011), cited from their observations that in the case of adaptive decision making, practitioners often refer to adaptation as non-continuous minor alterations on existing actions. They further identified that adaptation is commonly recognised as a means to prolong current practices, whilst disregarding the need for transformation (Smith *et al.,* 2011). The problem with this approach is that it fosters short-term planning and rigid decision making that ultimately results in coping as appose to adapting. If objectives remain unchanged in the light of climate variability then adaptive capacity is limited (Smith, *et al.,* 2011).

2.5 Business of water management in mining

Social and environmental factors influence water management but ultimately every decision has to make business sense. This sentiment is shared by most in the corporate space as meeting targets that not only generate profits but increases shareholder investment is crucial in the mining industry (Koch *et al*., 2005; Dold, 2008; Miranda and Sauer, 2010). The financial implications of poorly managed water are very costly. The literature emphasises that in order to achieve sustainable business, namely fulfilling obligations that enhance all six capitals of sustainable business there are three critical water services that need to be carefully managed (Koch *et al*., 2005; Dold, 2008; Miranda and Sauer, 2010).

- The activities and governance involved in mineral production during the mine life cycle,
- The rehabilitation and preservation of the environment where mining takes place and the surrounding areas (zone of influence), and,
- The balance of social engagement.

Dold (2008), maintains that these three water services form the basis of how mine water is managed in the business context. They also determine the potential risks associated with maintaining water systems and consequently, how these operational risks influence strategic risks at corporate level (Table 3) (Koch *et al*., 2005; Dold, 2008; Miranda and Sauer, 2010). As shown in Table 3, too often inadequate water management has resulted in harmful social and environmental impacts, the outcomes of which have crippled several mining companies. In an age of globalization and social media, reputation has rapidly become one of the most valued yet variable factors (Koch *et al*., 2005; Dold, 2008; Miranda and Sauer, 2010). A good reputation is highly sought after as we live in a society where people are not only aware of their rights and the rights of others, but they are also not afraid to advocate on behalf of others. Subsequently mining companies are forced to tread carefully. Beyond social impacts, a poor reputation is severely detrimental as shareholders lose confidence in the company. This loss of confidence contributes to reduced shareholder value and investment (Koch *et al*., 2005; Dold, 2008; Miranda and Sauer, 2010). That said, the value of good water management is not only in the form of saving costs, adhering to regulations or reducing water footprint it is also in earning approval, collaborating with nearby communities and industries, as well as maintaining a competitive edge in the industry.

Table 3: Summary of operational and strategic drivers and the possible impacts on business performance.

	Drivers	Possible impacts on business performance
Operational Level	**Poor water quality**	Mismanagement of water quality can compromise production entirely from, reduced mineral recovery to decreased product quality. There are additional costs involved in storing and treating water. Many examples exist where tailings storage facilities have failed causing major environmental and social impacts resulting in significant fines and compensation.
	Low water quantity	Inadequate management of water quantity can lead to water shortages. This is costly because having to externally source water at high rates could lead to operating at a loss. Water shortages also limit mineral recovery and eventually supply targets are not met.
	Excessive water use	Inefficient water use has been associated with penalties from regulatory bodies. The penalties could also present in the form of hidden costs i.e. expensive closure legacies, rehabilitation, preservation and water volume charges.
Strategic Level	**Regulatory approvals**	Companies that manage water above-standard tend to not only earn a good reputation but they also experience less difficulty acquiring regulatory approvals.
	Access to mineral resources	Good practices and reputation have also been linked with greater access to mineral resources in water stressed regions.
	Attracting human capital	Employees are more likely to join companies that have a good reputation. Such companies tend to retain a skilled workforce.
	Maintaining shareholder value	Poor reputation has many implications from hefty regulatory fines, deferred environmental approvals, loss of social consent and competitive advantage. The impacts of which is reduced company performance which could result in decreased shareholder value and investment.
	Retaining social consent	Sub-standard engagement with communities could result in major financial implications. The consequences of which could lead to protests, production losses, mine shutdown, damaged reputations and ultimately loss of

		shareholder investment. Although the impacts of operational risks are more direct, social opposition could result in accumulative long term losses.
	Public views on social responsibility	Beyond the local community's approval, general public perception also contributes to the reputation of a mining company. Since a lot of mineral deposits are located in under-developed societies mining companies are usually expected to contribute further to empowering local communities. These expectations could be achieved with a layered approach, one that not only caters to the needs of the local community but to the expectations of the general public as well.

Source: Adapted from (Koch *et al.,* 2005; Dold, 2008; Miranda and Sauer, 2010).

2.6 Governance of water management in mining

Governance is a term generally used to describe structures consisting of people at various levels, be it state departments, businesses, individuals or non-governmental organisations. Governance encompasses the processes and systems that guide decision making (Budds 2012). Governance is widespread across all levels in public and private sectors. In the mining industry governance can be divided into categories including corporate, government and collaboration between the two (Budds 2012).

2.6.1 Internal

Corporate governance plays an integral role of guidance across the entire mining company, and so the direction provided has to be clear and transparent. Mining industries have sets of regulations they abide by. At corporate level decision making and strategies are influenced by a variety of standards, policy and guidelines. Usually each company incorporates several international and local regulations into their internal policy. At the top level is the board of directors, this body is responsible for strategic water management from corporate to site level. Ultimately this board needs to ensure that each division within the company achieves the goals they set out efficiently and effectively (Kolk and Pinkse, 2004; Liphadzi and Vermaak, 2015; Barkemeyer *et al.,* 2015).

Usually an internal policy influences the company's objectives. According to the literature, an effective internal policy should contain practical, strategic goals, aimed towards exceeding the legal requirements for water management (Kolk and Pinkse, 2004; Liphadzi and Vermaak, 2015; Barkemeyer *et al.,* 2015) Therefore a clear strategy on how to approach challenges has to be established from the planning stage through to execution. Although internal policies exist, many companies struggle with implementation (Kolk and Pinkse, 2004; Liphadzi and Vermaak, 2015; Barkemeyer *et al.,* 2015). Kolk and Pinkse (2004) maintain that this is particularly due to lack of expertise, efficient technology, finances and willingness. On the contrary Barkemeyer *et al.,* (2015) stress, that too often companies claim to not have sufficient finances to escape properly managing their water resources.

2.6.2 External

In 2013 and 2014 the World Economic Forum highlighted water management as a matter of global urgency, identifying water scarcity and water-related weather events within the top 10 global risks (Budds 2012). They further stressed that shifts in physical landscapes and socio-economic settings will require innovative water management approaches (Budds 2012). Given that water is integral to mining, smart water management including water governance are critical to business sustainability as well as climate resilience. Water governance encompasses resolving conflicts and co-operative decision-making, thereby encouraging accountability and transparency throughout all governance structures. This, in turn, requires open dialogue where both the management and governance of water are discussed with all stakeholders (Vo and Green, 2000; Koch *et al.,* 2005; Mukheibir, 2008). Trends within literature designate the water crisis as a reflection of ineffective governance. Studies show that a shift towards decentralised governance incorporating more multiple-level and public-private participation is far more effective than traditional forms of governance. On the contrary others argue that this shift is restricted due to reduced consensus from opposing governance structures (Malzbender, *et al.,* 2005; Budds, 2012).

Currently a national adaptive water management strategy for the mining sector in the face of climate risks is lacking across the South African government. Notwithstanding this national omission, many mines have measures in place to deal with climate-related water issues. Global markets and investors have considerably influenced the South African mining industry. Mining establishments countrywide are increasingly aware of climate variability risks. As this research shows there are various risk assessments and management plans being implemented in order to increase shareholder investment and to remain competitive.

2.7 Conclusion

From a South African perspective, after scanning through various government policies, mining principles, sustainability reports, water stewardship programmes and best practice guidelines it is clear that several mining companies are currently facing challenges with water scarcity and flooding. Be that as it may, the mining sectors vulnerability to water scarcity and flooding, which could be further exacerbated by climate variability, is not extensively explored. Additionally there is a notable absence of policy or governance plans to steer mining companies, particularly in terms of adaptive water management in this sector. Therefore the following chapter will describe the approaches implemented by this study in order to contribute findings to this gap in knowledge.

Chapter 3: Methodology

3.1 Study design

The research presented here was undertaken using information from three sources: mining water policy documents (grouped here as governance), company reports and interviews.

3.1.1 Governance

A detailed document analysis was conducted examining publications that address adaptive water management in the mining sector. The openly available publications were obtained from national and associated governing structures (Figure. 4). This included a 5 year (2010-2014) evaluation of policies, acts, management plans, best practice guidelines and response strategies within the different structures. These particular governing structures were selected on the premise that each contributed regulations, guidelines and management plans in relation to the mining industry.

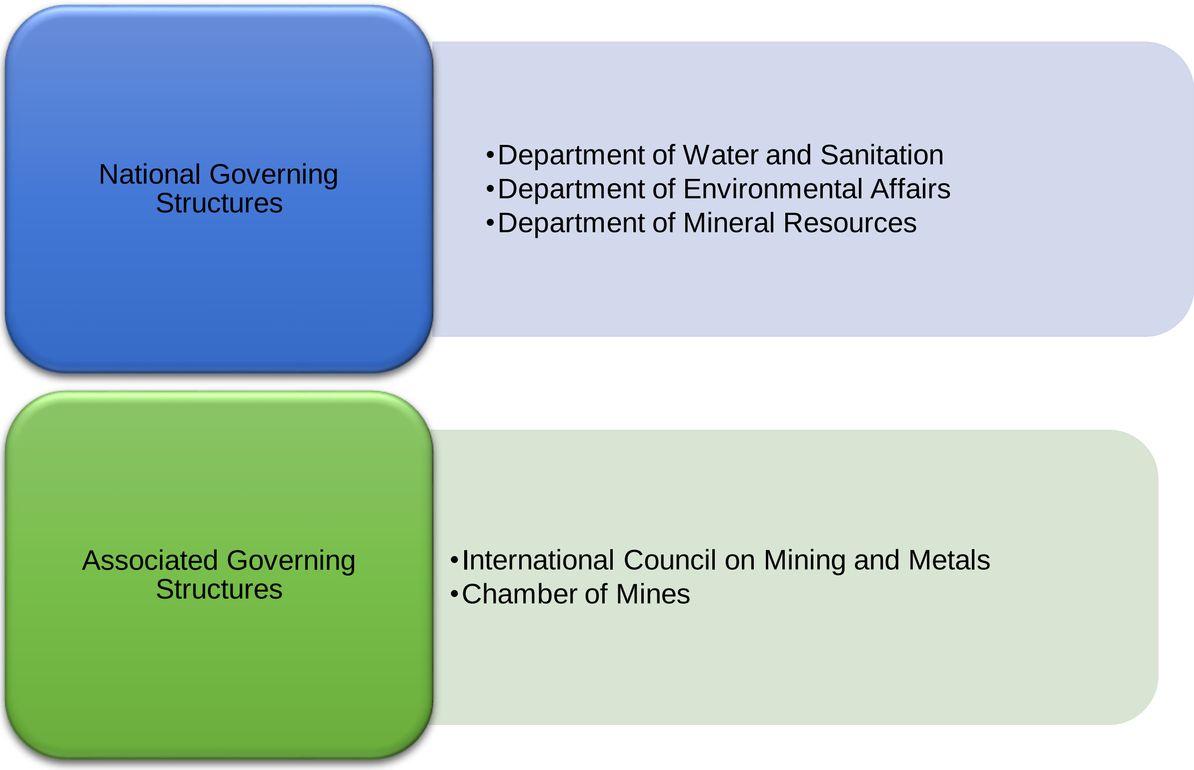

Figure 4: A summary of governing structures associated with the mining sector.

3.1.2 Company reports

A 5 year (2010-2014) review of the annual reports of each mining company was conducted. This included evaluating the annual water mandate from each company as well as sustainability, integrated, and financial reports. Initially mining risk registers were to be included but access to these was denied. A total of 5 companies were selected mainly to ensure consistency in the information provided by both the interviews and the company reports because only 5 companies agreed to participate in the interviews.

3.1.4 Company Interviews

Interviews were conducted at various mining head offices around the Johannesburg area (total of 5). These participating companies requested complete confidentiality, thus non-disclosure of company name and employee information. Of an initial sample of ten only five companies were derived based on agreement to participate in the interviews. Notably so, participating mining companies were medium-large scale companies therefore observations concerning water adaptation in small-medium scale companies is lacking.

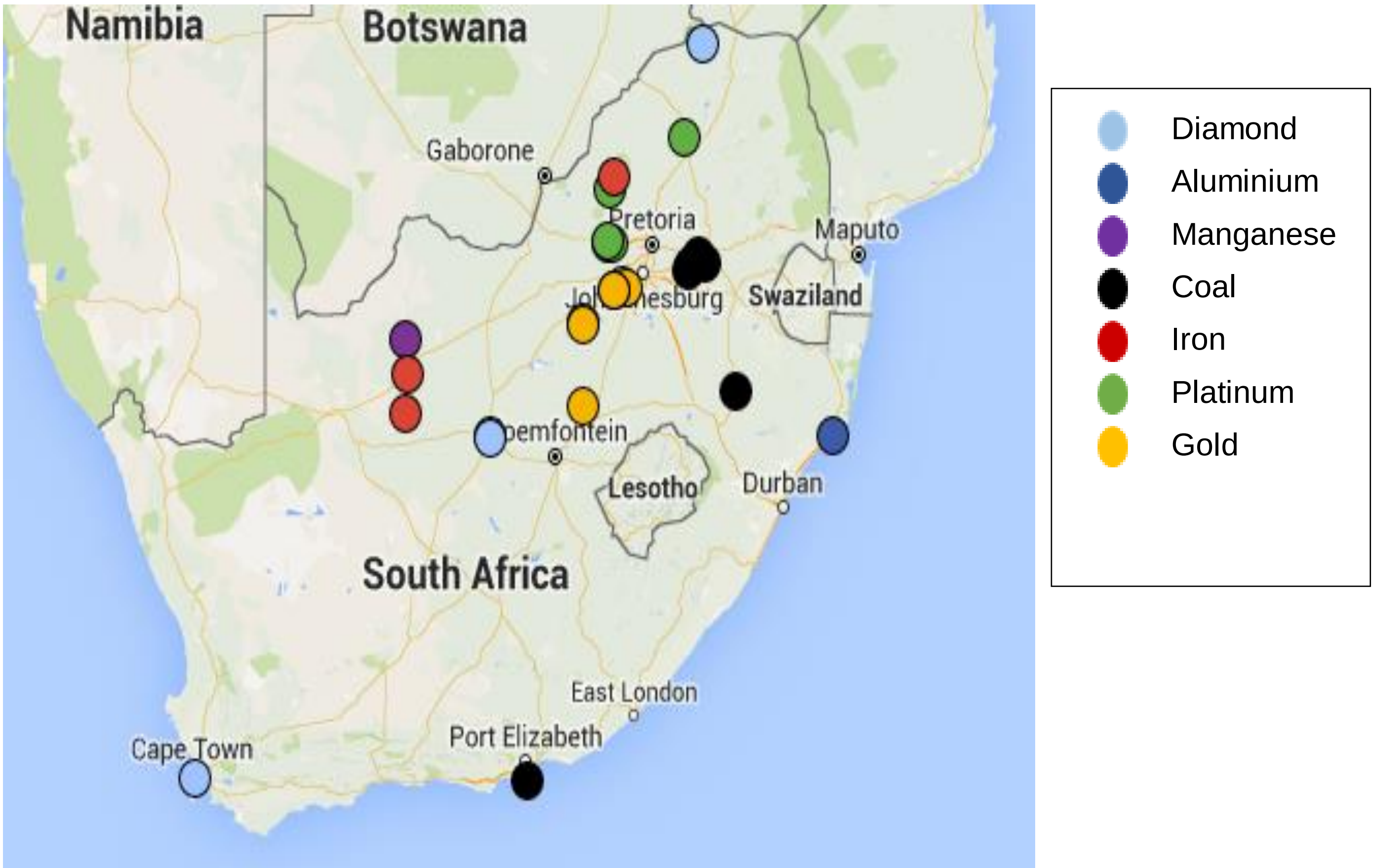

Figure 5: Spatial distribution of mining operations.

These mining companies were selected according to diversity and distribution. Water management is tailored to each operation according to the ore mined. As such 7 water intensive mined ores (Coal, Platinum, Aluminium, Diamonds, Manganese, Iron and Gold) were represented in this study. The spatial distribution of companies across all provinces is illustrated in Figure 5. The distribution of mining operation was also centred on the fact that each region has different (current and future) water risks (Figure 5). According to the 2013 Long Term Adaptation Scenarios (LTAS) report the western and southern parts of the country are projected to experience reduced rainfall whilst the eastern parts experience increased rainfall.

The interview analysis consisted of representatives heading the following departments within the mining company: sustainability, environmental management, water management and / or technical solutions. There were 5 individuals interviewed using a semi-structured open-ended interview schedule as well as unstructured discussion. Ethics clearance was obtained before proceeding with the interviews. Non-disclosure of the identity of respondents was followed for all 5 individuals.

3.3 Data analysis

The data analysis that follows is largely qualitative. The information from company reports, governance structures and the interviews was used to answer the research questions in the form of a detailed narrative (see questionnaires in Appendix 1). The data from the interviews provided information on water risks associated with climate variability and how mining companies were coping or, how they planned to deal with these risks, both currently and in the future (i.e. types and extensiveness of water management plans, frequency of monitoring, revisions and implementation of said plans as well as the feasibility of these plans). The transcribed data from these interviews was classified and categorised in order to identify patterns which were later grouped into themes. The three main themes that were explored included climate change awareness and considerations, adaptive water management plans and the extent of collaborations within governance.

3.3.1 Triangulation

Triangulation is widely defined as incorporating various approaches in order to produce comprehensive themes. Usually this approach is used when a single source of data or method of data collection is limited. Triangulation of several methods is also used to counter-balance the weakness in individual methods therefore strengthening the overall completeness of the findings.

According to Hsieh and Shannon (2005) the two main objectives of applying triangulation is to confirm and to complete the topic. Likewise triangulation is universally accepted as the convergence of several measures into one distinct construct. Ultimately they concluded that triangulation predominantly provided confirmation. The convergence of many data types is thought to also enhance the validity of the emerging concepts (Hsieh and Shannon, 2005; Jick, 2015). Patton (2002) advocates for the use of triangulation on the premise that the combination of methods strengthens the outcomes of a study. On the other hand Tuckett, (2005) maintains that triangulation is only effective if combining qualitative and quantitative research methods. Tuckett further argues that since each type of qualitative method is formulated based on distinct assumptions, it would be difficult to mix solely within qualitative methods.

3.3.2 Application of Triangulation

The type of triangulation used was a triangulation of sources to examine consistencies and discrepancies of several information sources, for instance:

- Reviewing publications from different time periods i.e. 2010-2014
- Evaluating both the public setting (national policy and international guidelines) and private setting (individual interviews and company reports).
- Comparing different viewpoints, for example different types of mines are situated across the country which all have different approaches to water management. Likewise the interview participants represented various departments i.e. sustainability or water management.

The information from the companies' reports together with national and international documentation (e.g. the water stewardship frameworks, best practice guidelines on water management and water resource protection) were triangulated to ensure that the responses gained in the interviews are compared and cross validated (Figure 6). This approach using multiple sources is applicable when there is limited research and academic literature available which why it was selected for this study (Tuckett, 2005; Jick, 2015).

The information gathered from the different sources was combined into themes that convey diverse viewpoints on adaptive water management. These themes were influenced by some of the key issues emerging in the global literature as highlighted in Table 2 and 3. A central theme such as adaptive water management was interrogated by examining the approaches from what is stipulated in governance structures, followed by how companies approached adaptation (short-term, long-term, incremental or transformational) as stated within company reports and finally how all these correlated with what was obtained from the interviews (Figure 6).

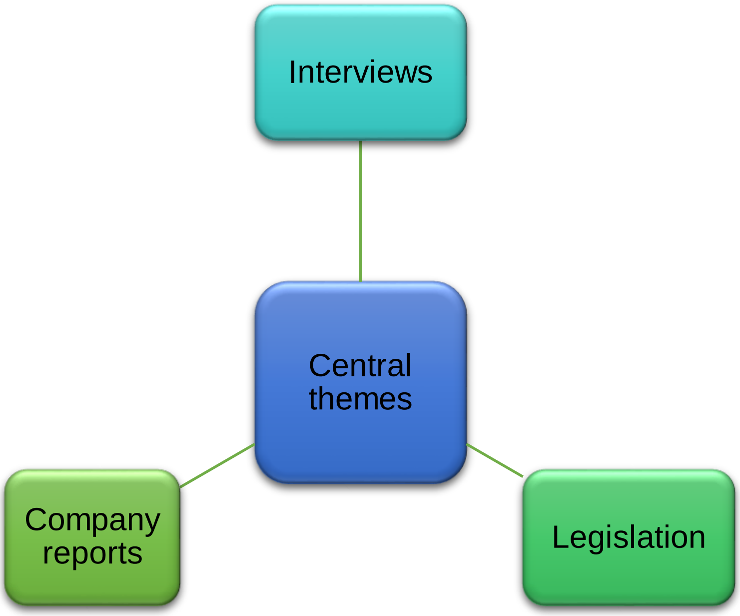

Figure 6: Triangulated Framework.

3.4 Ethics

The nature of this study involved human participants' therefore ethics approval was obtained with the following clearance number is H15/07/31.

3.5 Conclusion

Overall due to the limited information on adaptive water management in the mining industry, content from three sources (figure 6) was triangulated in order to produce an in-depth map of the current institutional design to identify climate-related water risks and the actions taken to adapt to climate variability in the South African mining landscape.

Chapter 4: Results and Discussion

4.1 Introduction

The mining industry is predisposed to changing water availability, frequent weather variations and demanding geographies. Therefore the aim of this study was to examine how 5 mining companies planned to manage water risks and opportunities, for periods of climate variability in their mining operations. This chapter serves to outline and discuss the findings according to what was put forward by mining water policy documents (grouped here as governance), company reports, as well as interviews. The purpose of this chapter is to assess current state of adaptive water management in the South African mining sector.

4.2 Results

This research aimed to explore 3 critical themes by building further on the issues indicated in Table 2 and 3 that influence adaptive water management by:

- Evaluating the extent of climate variability awareness and considerations in relation to water, as these are key to identifying, and assessing risks and opportunities as well as understanding the potential impacts to the company.
- Assessing the range of adaptive measures that inform approaches to water management.
- Examining whether collaborative efforts and partnerships exist between companies, governments and other industries.

The findings of which are outlined in this section.

4.2.1 Climate variability considerations

Governance

Table 4: Policy and guideline documents addressing climate-related water risks aimed at the mining industry.

Governance Structures	Publications
International Council on Mining and Metals (ICMM)	• Adapting to a changing climate: implications for mining and metals industry
Department of Mineral Resources (DMR)	• Documents were either absent or not publicly available
Department of Water and Sanitation (DWS)	• Best practice guidelines • Water conservation and water demand management guideline for the mining sector in South Africa
Department of Environmental Affairs (DEA)	• Long term adaptation scenarios: water sector
Chamber of Mines	• Documents were either absent or not publicly available

Source: ICMM, 2013. Pp 33.

The ICMM publication identified in Table 4, explains how climate variability could potentially impact water management for example, increasing temperatures, fluctuating rainfall patterns, rapid rise in sea levels and higher incidence of extreme weather events. This document illustrates the variety of physical, regulatory, reputational and financial risk associated with climate variability such as (ICMM, 2013), see also Figure 2:

- **Physical risks** including damage to infrastructure and assets as well as health and safety of employees and surrounding community. Securing and maintaining sufficient water supply.

- **Regulatory risks** in terms of being held liable and charged with fines due to climate-related mine water incidents (spills, leaks, decanting).
- **Reputational risks** in the form of diminished shareholder interest and the lack of community support.
- **Financial risks** such as higher operating and insurance costs as well as the absence of funds during unexpected replacement and maintenance of infrastructure.

In this ICMM report, climate implications were grouped into three categories namely; impacts to core operations, value chain and the broader network. There were noteworthy findings, for instance, risks to core operations included: decreased cooling and operating efficiency of machinery and equipment as a result of high temperatures, reduced durability of surface structures caused by severe storms and rainfall, as well as the inability to efficiently implement evacuation and emergency responses due to limited access to functioning roads. Another significant finding was that efficient transportation of input materials and final products was integral to the value chain within the mining industry. According to this report, any form of marine or terrestrial transportation was highly susceptible to climate variability. In the case of terrestrial conditions, severe storms and flooding could potentially destroy roads, thus disrupting supply chains. As for the marine settings, rising sea levels could disrupt product shipping and port operations ultimately delaying product delivery and resulting in high operational losses.

There are three national governing structures that influence the mining sector in South Africa (the DWA, the DEA and the DMR). The DWA best practice guidelines (BPGs) consisted of a series of 15 official publications. Although each guideline was tailored to a specific theme/aspect of water management most of them could be used concurrently. Collectively the BPGs explored each aspect of water management at mining operations. As shown in Table 5, these guidelines mentioned climate concerns pertaining to water management.

The underlying theme of the WC/WDM guideline for the mining sector in South Africa was water efficacy through water conservation and demand management. Although this document summarized overall objectives as well as the potential constraints and opportunities associated with Water Conservation and Water Demand in these sectors this document lacked information on climate variability (Table 5).

Table 5: Summary of climate-related water considerations in the Department of Water and Sanitation.

Publications	Climate considerations
Best practice guidelines	• Rise in global temperatures • Seasonal variation risks • Management of water during periods of drought and flooding • Examining flood variation risks • Impacts of extreme climate conditions on water quantity and quality (including site operations and downstream users).
WC/WDM guideline for the mining sector in South Africa	• Conservation of the environment, ecology and water resources. • Continuous improvement of water efficiency programs that combat water shortages and scarcity.

Source: Adapted from DWA, 2000 and DWAF, 2008.

The DEA extensively explains the climate risks pertaining to water in the *Long-term Adaptation Scenarios: water sector (DEA, 2013)*. The difference, however, was that these scenarios were primarily wide ranging examining water risks in national, provincial and zonal levels with not much focus one specific industry. This publication emphasised that mining operations would likely encounter water shortages and acid mine drainage. Furthermore this report cautioned that dense regions (i.e. areas with several agricultural and mining operations) would be confronted with competition for limited water resources.

The most important finding was that the DMR had no publications or guidelines that reported on climate variability in relation to water management. The DMR largely provided guidelines on closure as well health and safety practices on mine operations. Likewise there was an absence of guidelines from Chamber of Mines, addressing climate variation in relation to water management.

Company reports

Upon reviewing the company reports it was evident that water played a crucial role in operations, business strategy (i.e. financial, reputational and regulatory implications) and community engagement (i.e. social licence to operate, community development, water quality and water supply). Based on these reports regulatory risks have risen from 2010-2014 (Figure 7). Companies conveyed severe concerns in relation to acquiring and renewing water permits. They emphasized that water scarcity could delay water authorisation processes or result in retracted water licences.

The main trend identified was that every mining company highlighted their water usage data each year and compared usage patterns across one or more years. According to the company reports, most companies are meeting their water consumption or withdrawal annual targets. From the reports alone, it is difficult to compare the amount of water consumed across companies, as each mining company uses either a percentage or internal unit to report their water consumption. Furthermore most companies described their water consumption as a group/global total instead of country/region amount.

The coverage of issues relating to water quality was similar as every company described how their current water quality affected their operations each year. As shown in Figure 7, companies are reporting on water quality incidents (mostly discharge or overflowing water) on an annual basis from 2010-2014. Moreover, companies reported the volumes of water discharged as well as the frequency and severity of incidents that occurred annually. Interestingly, company reports linked the incidents of discharge or overflowing water to heavy rainfall conditions.

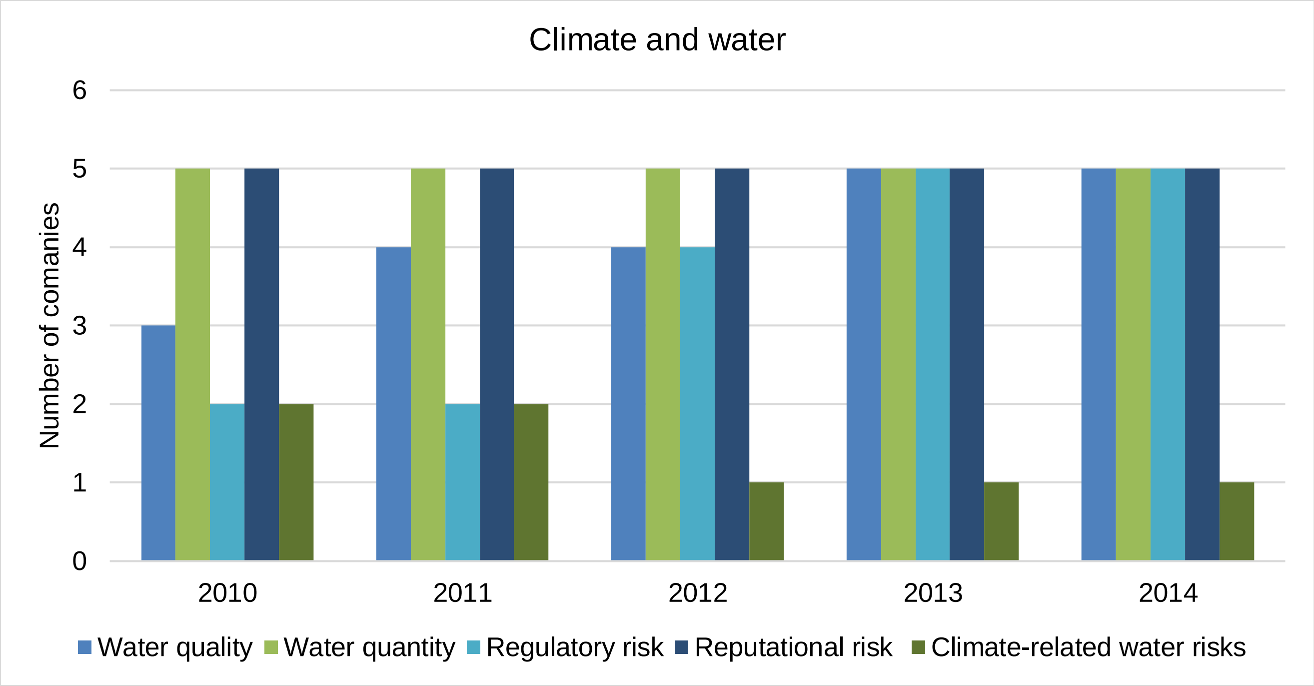

Figure 7: Climate and water issues in company reports (2010-2014).

As illustrated in Figure 6, 2 out of 5 reports described water concerns associated with climate variability in 2010 and 2011 as cited below:

> *"Mines are in already water-stressed areas. Climate models are predicting significant changes to rainfall, which will affect the availability and accessibility of water."* (Anglo American, 2010)

> *"Unreliable water access, and changes in precipitation extremes and droughts pose significant operational risks."* (Anglo American, 2010)

> *"The high levels of uncertainty pertaining to climate change make it difficult to estimate actual change and subsequently manage impacts."* (Goldfields, 2011)

Additional issues such as increasing demand and competition for water resources, supply shortages, cost escalations and more stringent regulation were also described. From 2012-2014 only one company reported on water risks linked to climate variability (Figure 7). The concerns included potential flooding, drought occurrence, disruptions to the mine-supply chain; increasing ambient temperatures affecting mine ventilation and safety of employees; the effects of high evaporation on water-recovery rates and buffer-storage capacity.

Interviews

Climate variability was estimated to influence both current and future climatic conditions including: rainfall patterns (drought and flooding) as well as temperature variation. Based on the Figure 8, however, only 2 out of 5 mining companies declared water scarcity as a risk between 1-5 years and > 5 years. In total, only one company is currently facing water scarcity as a major risk in their mining operations. They also stressed that incidences of water scarcity could potentially compromise current operations and future prospects as regulators and communities could become more reluctant to grant water-use permits or accept additional users. Moreover, this company stated the following;

> *"During a period of acute shortage of water occasioned by droughts and a series of heatwaves, the communities protested resulting in damage to a pump water station, which supplies the mine with water."* (Company 5, 2015)

In this case, water scarcity presented adverse impacts to operations, regulatory obstacles and social conflict, further indicative of the vulnerability this company faces.

On the contrary flooding was considered a major risk by the majority of companies investigated, as 4 out of 5 companies stressed the considerable implications of flooding. Some of the respondents mentioned that:

> *"Inter-annual climatic variability at our sites can result in flooding and excess water management risks. The risk of operational, plant/production disruption leading to reduced output may have a substantive impact on revenue."* (Company 3, 2015)

> *"There is a limited capacity of our pumping and pipe systems to pump water from the mine into the local water courses under controlled release conditions, therefore mining operations could be severely impacted due to flooding of opencast pits and certain underground areas"* (Company 1, 2015)

> *"Flooding disrupts mining and also has local community and stakeholder impacts that affect our employees and their families."* (Company 4, 2015)

These respondents continued to highlight that flooding could substantially delay the supply of products and services to operations and customers. Moreover this could result in increased transportation costs if products need to be transported further due to closure of access roads. One respondent indicated that local communities were extremely vulnerable to disruptions linked to flooding, particularly in regions where the mines supply communities with water. Other flooding-related risks included increased contamination of shallow ground water, failure of tailings facilities as well as compromised working conditions. According to the interviews performed, temperature variation, energy costs and increased operating costs are the most prevalent risks at each time frame (current, 1-5 years and > 5 years).

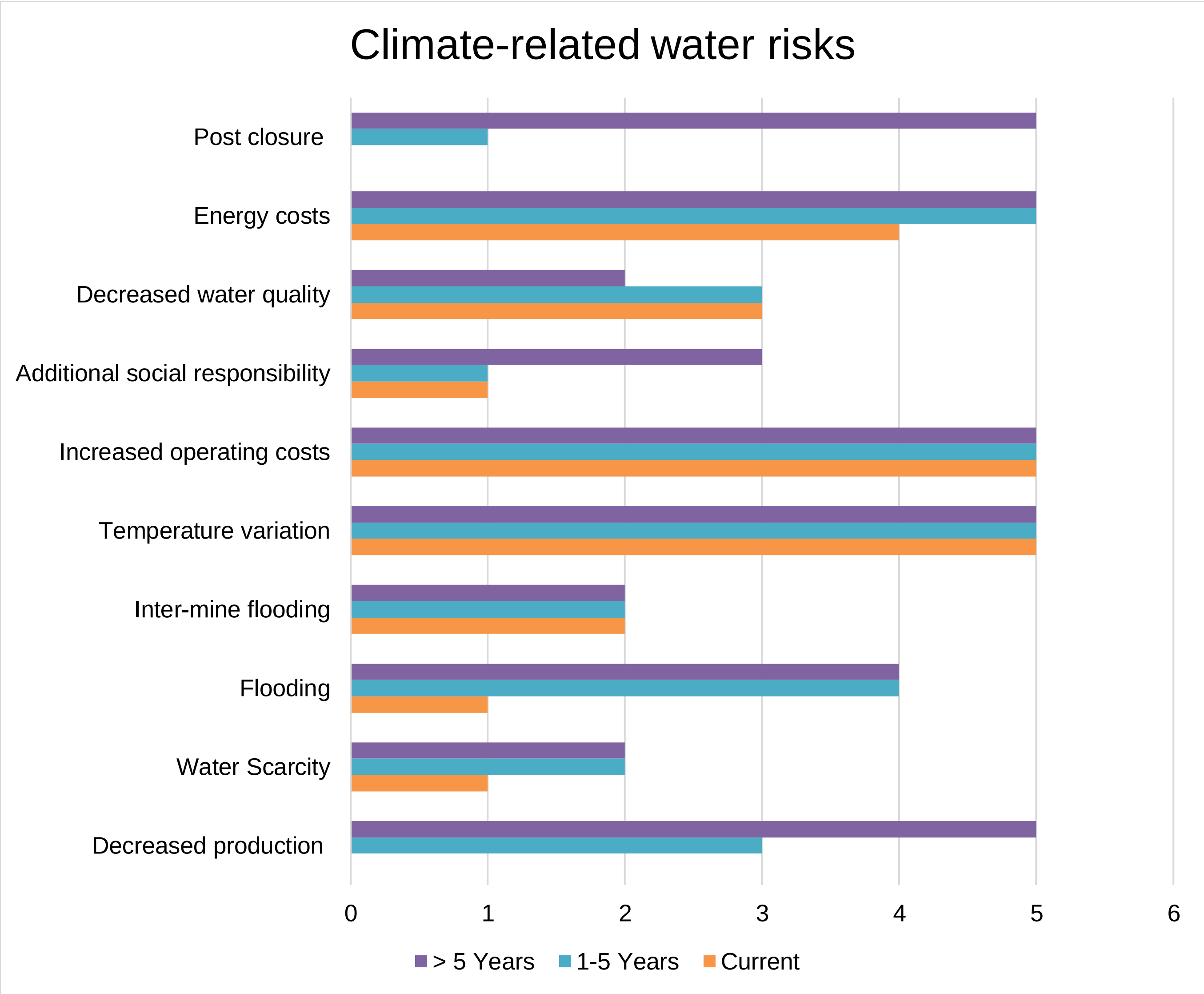

Figure 8: The current and future climate-related water risks profile.

4.2.2 Adaptive measures

Governance

The ICMM publication *Adapting to a changing climate: implications for mining and metals industry*, presented guidelines on adapting to climate change, providing key steps to enhancing resilience in water management. This report also included a framework informing approaches that were applicable at operational and corporate level. As shown in Table 6, the framework included themes followed by details on possible adaptation options that mining companies could implement in response to a changing climate.

Table 6: Climate variability response options.

<table>
<tr><th>Themes</th><th colspan="2">Response options</th></tr>
<tr><td>Increasing awareness</td><td colspan="2">• Circulating insights on climate adaptation approaches through teaching, workshops and forums
• Inform surrounding communities on climate variability impacts (water supply as well as health and safety)</td></tr>
<tr><td>Risk assessment</td><td colspan="2">• Short and long term risks as well as priority areas
• Structural integrity of infrastructure and site design
• Costs of mitigation vs. prevention</td></tr>
<tr><td>Adaptation planning</td><td colspan="2">• Incorporate targets into business strategies and policies
• Develop performance monitoring tools
• Integrate adaptation plans into existing plans</td></tr>
<tr><td rowspan="3">Adaptation actions</td><td>Prevention</td><td>• Reinforce infrastructure and assets to account for variable climate impacts
• Regularly monitor and maintain infrastructure and assets
• Develop early-warning systems for communities</td></tr>
<tr><td>Mitigation</td><td>• Enhance flexibility and capacity of infrastructure and assets
• Develop land-use and site expansion plans
• Improve natural buffers (protection against flooding)</td></tr>
<tr><td>Remediation</td><td>• Evaluate contingency plans</td></tr>
</table>

		• Incorporate climate variability considerations into existing restoration and remediation plans
Monitoring, evaluation and reporting	• Short and long term environmental and climate monitoring • Frequently examining structural integrity of infrastructure and site design • Regularly assessing the success of adaptation measures • Publicly disclosing adaption progress	

Source: ICMM, 2013. Pp 40-46.

As indicated in Table 6, these options were often driven by current risks, such as extreme weather conditions, or water scarcity, however, they also highlighted the benefits of preparing for future climate risks (i.e. frequent floods, severe drought or high temperature). More importantly, this framework emphasized that mining companies could incorporate adaptation measures into existing activities (Table 6). Most of companies interviewed in this study employed some of these response options. The most implemented options included engaging through forums, monitoring risks and reinforcing infrastructures.

The DWA BPG's incorporate aspects of adaptation by encouraging a life cycle approach that involves continuous risk assessments, monitoring, improving water management approaches and increasing the target performance criteria. The guideline describes undertaking mine water management with a holistic view across the entire life of the mine. This includes addressing water issues that may arise in the exploration, construction, operation, closure and post closure (Table 7). Further emphasis is placed on minimizing waste water production through efficient water use, recycling as well as conserving water resources. This guideline also encourages mines to adopt a risk-based approach in which mines are urged to evaluate current and long-term risks associated with mine activities, followed by minimising or mitigating the identified risks (Table 7). An important finding was that this document promoted continuous improvement as one of their key principles of mine water management. As such it was recommended that water management plans be reviewed and updated on a frequent basis. The selected companies are applying the DWA recommendations stipulated in Table 7. Pollution prevention, flood planning, storage efficiency and monitoring programmes were all identified in company reports, water disclosures and interviews.

Table 7: Summary of DWA Best practice guidelines (recommendations for managing water risks).

Aspect	Recommendations
Pollution	• Undertake geochemical assessments to evaluate long-term pollution • Minimise water contamination
Flooding	• Improve structural works • Meticulous site planning
Seepage/ Overflow	• Minimise seepage/overflow • Increase storage facility capacity
Monitoring Systems	• System should change as the mine and water management needs change. • Short and long term predictive monitoring

Source: DWAF, 2008.

As indicated in Table 8, the DEA presented climate variability responses associated with water in their publications, however, these adaptive recommendations were broad aimed at the entire water sector, not tailored to suite a specific industry. DEA also mentioned undertaking reconciliation studies that would assess the ecological and economic water requirements across the country. These studies would focus on addressing the feasibility of adapting to climate variability aimed at efficient water infrastructure.

Table 8: Summary of DEA recommendations for managing water risks.

Focus area	Recommendations
Making decisions that do not foreclose future options.	• Developing and maintaining healthy ecological infrastructure
Monitoring indicators	• Monitor hydrological, ecological and economic variables. • Developing responses to unanticipated events by identifying long-term alterations and trends.
Modify plans as circumstances change	• Update and review water management, contingency and infrastructure plans.

Source: DEA, 2013.

The DMR guidelines are primarily aimed at safety and health issues related to mine operations and lacked guidance on climate adaptation measures. Once again there were no guidelines from the Chamber of Mines.

Company reports

Companies are reporting on the frequency and types of monitoring that occur at their operations. 3 out of 5 companies disclosed their monitoring and risk identification methods (Figure 8). One company, for example, focused on monitoring water quality in order to detect issues such as acid mine drainage and contamination of underground plumes. This very same company introduced an automated continuous water monitoring system in order to increase the accuracy of water quality information captured. Three companies mentioned monitoring water quantity (surface and groundwater) in order to manage their water withdrawal quantities and shared water use on a basin scale.

As illustrated in Figure 8, 3 out of 5 companies mentioned atmospheric modelling in their reports. Some of the modelling performed included: plume models that explain the impact of tailings storage facilities on groundwater resources. One company described their modelling as an integrated water modelling system that determines once water levels have exceeded the required amount at site level (Figure 8). According to the reports every mining company has an internal assessment tool. Two companies have had the same water assessment tools from 2010-2014. Whilst one company introduced a new water assessment tool in 2010 that focuses primarily on water efficiency, two other companies reported updated versions of their assessment tools in 2014.

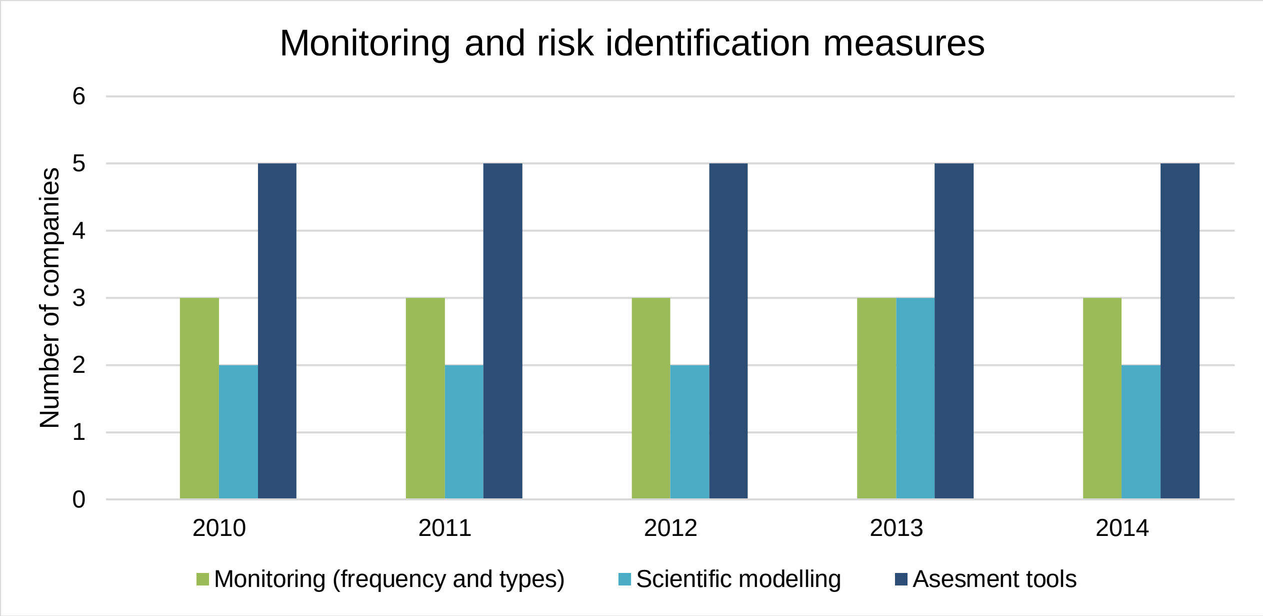

Figure 9: Monitoring and risk identification measures in company reports (2010-2014).

Water programmes or projects are common amongst all companies (Figure 9). One company's water programme focuses primarily on acid mine drainage issues using a combination of scientific modelling of plumes and continuous monitoring (of groundwater) to identify and mitigate water risks related to acid mine drainage.

Water efficiency was the most prevalent program across all the company reports (Figure 10). One company in particular designed an assessment tool that determines water efficiency targets by projecting future water demands if business were to continue as usual then adjusting for this by establishing a schedule of water saving indicators. The water targets are set based on the level of water security (i.e. limited water availability would result in more stringent water targets) and quantified as absolute reduction in total water consumption. Other water efficiency projects included, more effective recycling, reuse of water, dust suppression, dewatering of tailings and more efficient ore separation. A variety of water programmes were reported such as improving slimes density, using lower-quality water, returning excess groundwater to the aquifers, seepage interception using boreholes and drains.

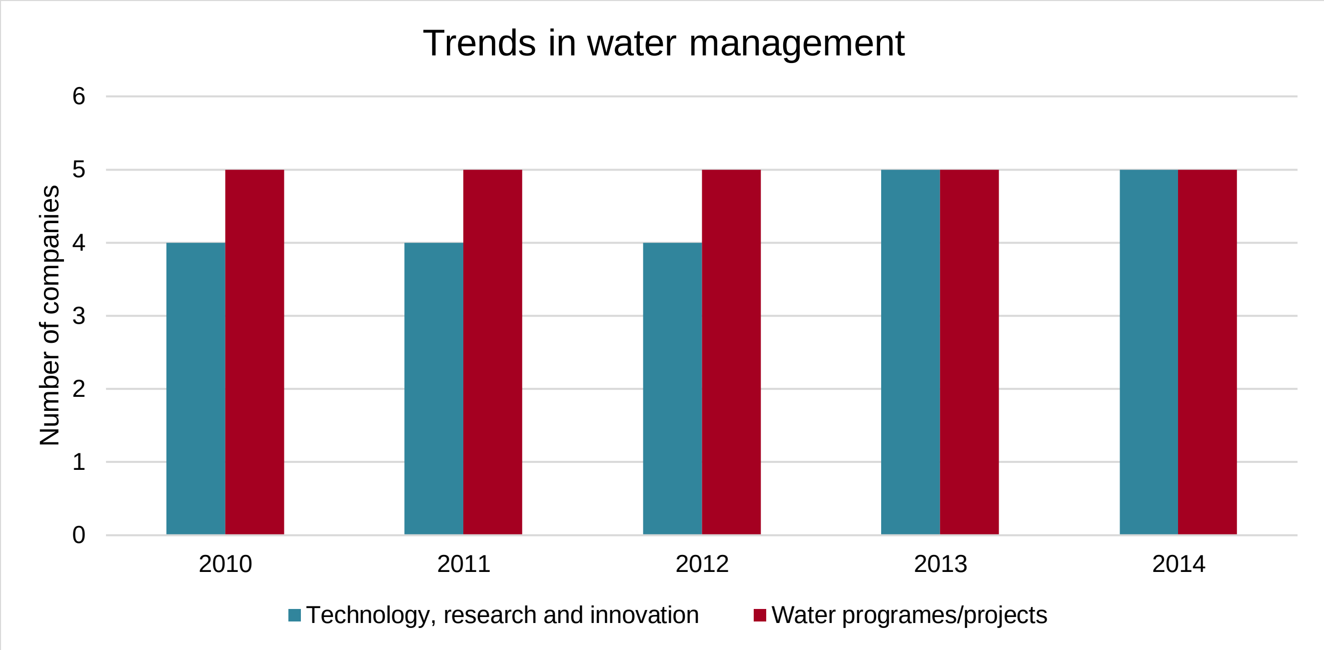

Figure 10: Trends in water management approaches in company reports (2010-2014).

These reports have demonstrated that technical solutions play a prominent role in water management approaches as shown in the regularity of reporting (Figure 10). Technical solutions involved the installations of water treatment plants, reverse osmosis plants, tailings storage facility dams and mobile plants.

Interviews

Although there were slight differences in approaches, the industry professionals that were interviewed, appeared to incorporate aspects of adaptive water management (i.e. preventing and mitigating risks) in their operations (Table 10).

Table 9: Climate-related response activities conducted by mining companies (interviews).

Focus area	Response activities
Frequency of modelling exercises	• According to all the participants, modelling exercises (including climatology and hydrogeology) were performed, on an annual basis the outcomes of which would form part of annual internal reviews. • For example one participant mentioned that they installed weather stations at every site to collect data every day in real time then after each year the data would be analysed and used to model climatic projections.

	• Additionally, one of the respondents explained that they conducted hydrogeological modelling to improve their understanding of the subterranean water flows, aquifer migration and pollution plumes from dams.
Frequency of water quality and quantity measurements	• All the participants mentioned that the quality of water was measured every day at different points on the mine. • There were also daily, weekly and monthly data collections and sampling of water done by environmental scientists. • According to the interviews, borehole and underground water level and quality testing occurred daily. • Some of these measurements were automated and could be accessed on computers remotely.
Enhancing flexibility of assets	• Two companies confirmed measuring their tailings capacity on a quarterly basis because flooding is problematic as tailings facilities have a certain capacity if a massive flood were to occur it would result in major health, safety and environmental implications (i.e. discharge of contaminated water into rivers and surrounding communities). • One participant emphasised that they had reinforced their storm water management systems with concrete channels to catch any contaminated runoff and channel it back to return water dams.
Rectifying previous structures	• Some companies were in the process of digging up unlined water dams as legislation did not require lining previously, whilst others were putting in entirely new return water dams and revegetating tailings facilities. • Mining operations are also in the midst of reducing ground water seepage by blasting tailings.

An important finding was that water management plans were revised, updated at each stage of mine cycle and audited annually by every company. As shown in (Table 9) all the mining companies frequently monitored and evaluated climate-related water risks. For instance at site-level water projects varied depending on the water catchment, hydrogeology, climatic conditions etc. Some of the types of programmes included:

- According to one participant, presently water shortages were highly ranked therefore various projects examining water security were implemented including efficiency projects which were intended to decrease water consumed at each phase of the mine. A key aspect of which was to investigate alternative extracting methods that use less water e.g. crushing and grinding that use less water, using different chemicals, placing evaporative covers, improving metering technology thus adding less water to slurry.

- Source water projects i.e. drilling of new wells, transportation of water from one mine to another using pipelines.
- Some mines have installed reverse osmosis plants in order to reduce the amount of water sourced from rand water. The plants then treat water to a potable standard which can then be reused in processing thus reducing water footprint for parts of the process that don’t require high quality water.
- Outflow end programmes exploring water reuse, recycling and recovery from tailings facilities.
- Treatment of water i.e. seepage collection treatment, natural treatment and passive treatment.
- Applying concurrent rehabilitation techniques by revegetating tailings facilities to combat dust issues and reduce the amount of water required to suppress dust.
- Improving storm water management systems by installing concrete channels to catch any contaminated runoff and channel it aback to return water dam.

4.2.3 Collaboration

Governance

Co-operative partnerships within governance structures do exist on a national scale. For example, the DMR and the Chamber of mines, these two governing structures have facilitated region specific workshops and water forums collaborating with mining houses, local communities and surrounding industries to address issues relating to water availability and quality. They have engaged with various parties (e.g. CSIR, Mintek) to investigate long-term solutions towards acid mine drainage and mine closure. The Chamber of Mines itself is a partnership of several mining companies in South Africa.

Based on the 2013, ICMM publication, collaboration is integral to adapting to climate variability. In fact, a section in this document describes options on creating co-operative partnerships. For example:

- Developing and testing strategies throughout various levels namely, trade and industry associations, government, society, industry consultants and academia
- Participating in regular reviews and improvements of industry and international standards
- Consulting on the development of policy and regulations as well as adaptation programs
- Engaging with investors to improve the disclosure of climate variability risks and opportunities

Source: ICMM, 2013.

Company reports

As illustrated in Figure 11, there was a considerably low amount of cross-industry collaboration being reported by mining companies as only one company acknowledged enduring partnerships with national industry associations, the World Business Council for Sustainable Development, the Integrated Water Task Team for South Africa and the South African Water and Energy Forum. The same company cited engaging with Eskom (a power utility) to research water issues related to rehabilitation and closure.

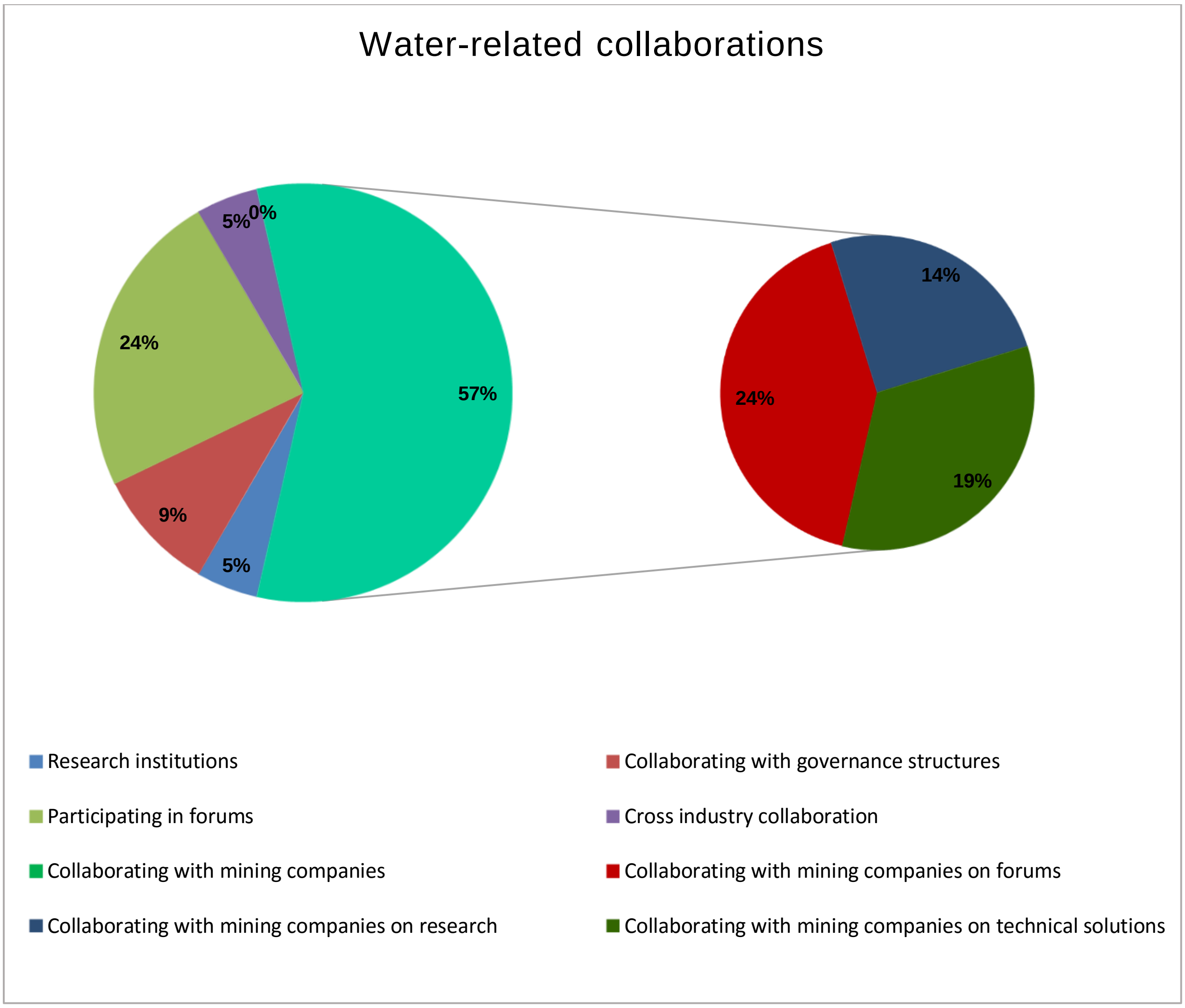

Figure 11: Distribution of water-related collaborations in the mining industry.

An interesting finding was that when governance structures were mentioned it was mainly in the context of compliance and adhering to regulations stipulated by the various structures (i.e. DWA, DEA and DMR). That said, some companies did mention partnering up with governance structures to establish water forums for example a water project that included several mining companies and multiple stakeholders (government and community representatives) with the aim to address sustainable development issues pertaining to water delivery in that region. Some reports described community engagements concerning managing shared water resources.

As illustrated in Figure 11, water forums formed the bulk of collaborative initiatives within the industry. Most forums such as the Strategic Water Partners Network programme included companies from various industries (mining, energy, agriculture etc.) local communities and municipalities engaged on water issues (either related to water quality or quantity).

According to company reports, collaboration was mainly in the form of partnerships with other mining companies (Figure 11). Additionally all companies mentioned engaging with fellow mining companies on developing technical solutions such as constructing water dams and water treatment plants. A particularly interesting finding was that two mining companies collaborated with their local municipality to build a water treatment plant indicating partnerships with local governance structures as well. One company in particular reported collaborating with academic institutions on climate modelling and water technology projects with the aim to increase water efficiency. Notably every company mentioned incorporating ICMM guidelines into their water management plans and complying with regulations stipulated by the Department of Water Affairs, Department of Environmental Affairs and Department of Mineral Resources (Figure 11).

Interviews

Mining collaborations are considerably increasing in South Africa as several companies are teaming up to manage shared water resources (Figure 12). Three respondents mentioned partnerships with other mining houses to build water facilities. These facilities included water treatment plants, water dams, and a water reclamation plant. As shown in Figure 12, participating companies are partnering up within the mining sector and externally collaborating with various industries to formulate water management solutions. One participant mentioned working with Coca Cola, Dell and Siemens on water management solutions. They further emphasised that they frequently used these non-mining companies' water efficiency programmes as a benchmark.

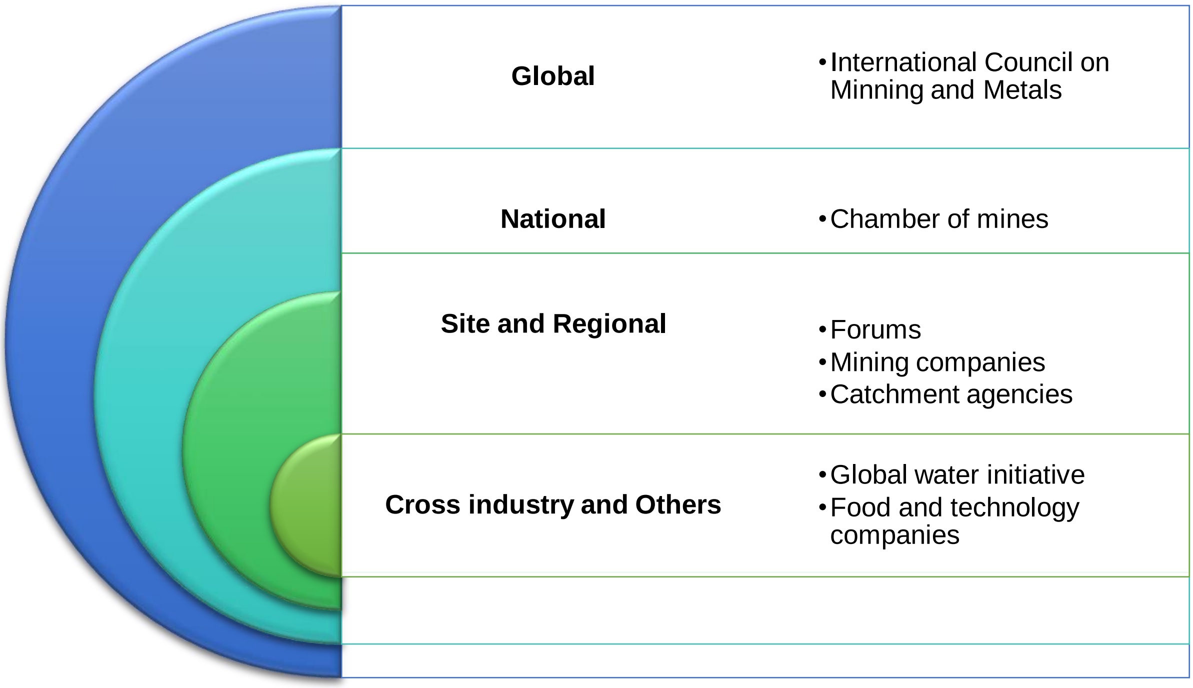

Figure 12: Organisations collaborating on water management.

At regional levels there are forums and informal meetings that take place tackling catchment based water management (Figure 12). These tend to be a collaboration between neighbouring mining houses, nearby industries, communities and local municipalities. A significant finding was that one participant mentioned a government-led national initiative currently underway, where various levels of governments (national, provincial and local) from different departments (i.e. Department of Water and Sanitation, Department of Mineral Resources and Department of Environmental Affairs, Chamber of mine etc.) hosting several forums and workshops with mining houses, unions, non-governmental organisations, and other industries (agriculture and energy etc.) with the aim to develop solutions related to water shortages, scarcity and managing water resources in the face of climate variability. This respondent was delighted to engage in this initiative, further stressing the need to work closely with NGO's and regulators in order to integrate diverse views on finding solutions as well as building collations.

One respondent described a forum they hosted in partnership with the Chamber of Mines to address developments such as: the national water resources strategy, water pricing structures, demand-side management targets for the sector, and the development of a system to charge waste-water discharges (Figure 12).

Lastly the ICMM was ranked as the most collaborative organisation by all participating companies. This is largely due to the consultations and workshops led by the ICMM which result in the publications of guidelines such as, in 2015, the catchment based water management guidelines that had contributions from South African mining companies. This particular guideline assists with the identification, assessment and approaches in towards managing water at a catchment level.

4.3 Discussion

4.3.1 Climate variability considerations

After converging the information collected from mining companies some discrepancies were noted between the information from the interviews and the company reports. Firstly, a broad understanding of climate considerations came across from the interviews, as water risks associated with climate variability, were outlined in three time frames (current, 1-5 years and > 5 years). Furthermore, each respondent was able to discuss their water risk profiles in terms of the potential impacts to mining operations within these frames as well. In the company reports, however, very few companies incorporated climate considerations into their water narrative. From 2010-2014 an average of only two companies mentioned climate-related water risks, describing issues such as: flooding, drought, the effects of high evaporation on water-recovery rates and buffer-storage capacity. Nonetheless companies predominantly reported water incidents (i.e. situations where excessive rainfall cause overflowing of tailings storage facilities contaminating nearby dams and rivers). Even though these incidents were reported there was no mention of how these companies intended to predict (through risks assessments) or prevent these incidents from reoccurring especially in relation to future climate uncertainty.

Secondly the findings from this study suggest that the information provided by company reports was less explicit relative to the interviews. In the company reports water issues related to quality and quantity were discussed but the consequences were limited to discharge incidents and water savings achieved. Alternatively during the interviews when participants were asked to explain the impacts associated with water risks; their responses were thorough, indicating not only climate related water risks, but how these risks affected their mining operations as well. Subsequently it appears as if the interviews revealed a high degree of vulnerability within the mining sector.

Of the five mining companies that participated in this survey a key finding was that temperature variation and increased operating costs are equally noted at each time frame (current, 1-5 years and > 5 years) by every participant. In terms of temperature the main concerns involved cooling and ventilation costs as well as the health and safety of employees. According to Adler *et al.,* (2007) temperature variation usually affects mines according to the depth of mine shafts. Heat (measured as wet bulb temperature) usually increases with depth and therefore temperature has to remain at regulated level to maintain safe working conditions. Since South Africa has some of the deepest underground mines; increases in climate variability could increase wet bulb temperature ultimately increasing cooling and ventilation costs required to ensure the health and safety of employees (Adler *et al.,* 2007).

It is important to note that although only 5 companies participated in the interviews, seven water intensive mined ores (Coal, Platinum, Aluminium, Diamonds, Manganese, Iron and Gold) were represented in this study. The consensus amongst all participants was that climate-related water risks posed a significant threat particularly in the form of additional costs. Any increase in running costs could ultimately impact social responsibility within communities as supplying water to them will be costly (Miranda and Sauer, 2010).

With regards to the South African mining sector the extent of climate variability awareness and considerations within governance structures varies. On a national scale the DWA and DEA both disclose the potential impacts of climate change which are emphasised through publications such as the Long Term Adaptation Scenarios and the Best Practice Guidelines. Even so the outcomes of this study suggests that South African governance structures such as Department of Mineral Resources and Chamber of mines are slow to respond to climate-related water risks in the mining sector. It is vital to understand that national government structures, in most instances, are still the institutionally legitimized unit responsible for national interests and to provide guidance (Malzbender, *et al.,* 2005; Budds, 2012). Therefore the deficit of policy from the DMR and Chamber of mines on adaptive water management in the mining industry is of critical concern.

On the contrary, the ICMM 2013 adaptation guideline describes the importance of risk and opportunity assessment. They maintain that incorporating climate variability considerations into risk assessment activities helps with not only identifying climate-related water risks, but that these practices assist with prioritizing the likelihood and magnitude of the impacts associated with these risks. They further stress that by performing risk assessments companies are more like to discover opportunities pertaining to climate variability. Ultimately they encourage considering climate variability in order to inform adaptation responses (ICMM, 2013).

The findings of this study indicate discrepancies between the interviews conducted, the company reports and the governance documents. Even more so, these finding indicate a huge gap between international and national guidance. This statement is validated by the lack of suitable water guidelines particularly from DWA, DMR and

4.3.2 Adaptive measures

The findings of this study, particularly the interviews, suggest that mining companies in South Africa are making an effort to cope with climate variability in their approaches to water management short term and long term. For example, applying concurrent rehabilitation techniques by revegetating tailings facilities. This concurrent rehabilitation is effective in combating dust and reducing the amount of water required to suppress dust but most importantly it is a proactive approach to rehabilitation. This form of rehabilitation is recommended because it reduces the amount of water used during operation and during the mine closure as well, thereby beneficial both in the short and long term. From the company reports it is clear that mining companies predominantly encounter incidents related to surface run-off and tailings storage facilities discharges (usually due to heavy rainfall).

Another example of how mines are coping with climate variability is through enhancing the flexibility of their assets by installing concrete channels to catch any contaminated runoff and channel it back to a return water dam. In so doing, this improves the storm water management system and minimises the likelihood of discharged water contaminating nearby rivers and dams. Overall the responses from the interviews gave a clearer explanation of why certain adaptive measure were prioritized over others (i.e. the high rate of incidents prompting the improvement in storm water management system).

As indicated by one of the respondents, mining companies in South Africa either encounter too much or too little water in their mining operations. That said, the findings of this study suggest that mining companies are planning to deal with future climate variability by modifying their current water practices. One repeated finding was that each company has a water efficiency program. These plans include: more effective recycling and reuse of water, dust suppression, dewatering of tailings and more efficient ore separation. A variety of water programmes were reported such as improved slimes density, using lower-quality water where practicable; returning excess groundwater to the aquifers, seepage interception using boreholes and drains. The main objective of these programmes was to reduce the amount of water used in each cycle, and to also determine water consumption using reliable metrics. According to most respondents the benefit of increasing water efficiency are reduced operating costs and dependence on large amounts of water. Learning to use less water at this stage is critical, as climate variability has the potential to affect long-term and short-term abundance and quality of water resources (Schulze, 2011).

Of all the governance structures that influence mining in South Africa it is evident that only the ICMM (international) and the DWA (national) are developing guidelines for water management in mining. In terms of the ICMM guidelines companies that are members are required to adhere to these guidelines. Likewise, this applies to the DWA guidelines as compliance is mandatory for maintaining water use licences.

ICMM guidelines specifically outlined water management approaches towards adapting to climate variability. It is evident from the company reports, company water disclosures and interviews that these guidelines along with those from the DWA on water efficiency are being implemented within the South African mining sector. South Africa has been identified as being amongst the most vulnerable to climate change. Numerous studies projected increased frequency and intensity of extreme weather events such as floods and droughts (Vo and Green, 2000; Faramarzi *et al.,* 2013; Kusangaya *et al.,* 2014). Hence the projected impacts of climate change on the water sector are likely to be considerable. Yet governing institutions are still slow to respond to this issue. For instance various levels of governance (e.g. Department of Mineral Resources and Chamber of mines) are established; however, as shown in this research, they often do not have the guidelines in place to deal with the challenges associated with water adaptation in the mining sector.

4.3.3 Collaboration

The ICMM have dominated many collaborative engagements from workshops, to consultations and ultimately the publications of guidelines that are publicly available. Hence guidance resources stem mainly from the ICMM (international) and the DWA as well as DEA (national), thus indicating minimal contributions from other national governance structures such as the DMR. With respect to publications such as guidelines and water policies the findings suggest that the Chamber of Mines was not active, however, several mining companies reported collaborating or participating in forums hosted by the Chamber of mines. Findings from this study suggest a lack of integration between the national governing bodies (i.e. DWA, DEA, and DMR) as well as the chamber of mines.

A key trend highlighted by this study is that many mining companies collaborate and engage within the mining sector. The outcomes of these partnerships vary, from building water management infrastructure to participating in local forums. According to Darling and Jones (2012), The opportunity of preventing conflicts over water can be pioneered by companies willing to invest in internal alignment, strategic communication, and co-management with local stakeholders including communities, governments and other industry players. They further stress that this component of a mine's life cycle is largely non-technical, but may be vital for starting or continuing economic activity in a region where communities and industry depend on water for operations and livelihoods.

4.4 Conclusion

Climate variability in isolation from other risks is an immense threat to the business of mining because of the adverse impacts to assets, infrastructure, and supply chain, working conditions and operations as a whole. What is more is that water plays a fundamental role in the growth and profitability of mining companies, as it is required in most mining processes. Therefore understanding the relationship between climate variability and water; the risks they pose to business as well as developing response measures that are robust to short-term and long-term climate impacts is vital in the mining sector as a whole.

It is evident that mining companies are currently trying to cope with climate risk by incorporating recommendations set out in the ICMM and DWA guidelines. They are also planning for future impacts (adaptation). It is clear, however that it is not a national imperative to adaptively manage water resources, as the two governing bodies (DMR and Chamber of Mines) that directly preside over the mining sector have not contributed any policy or guidelines to this effect. That said the DEA, DWA and international based ICMM have been facilitating adaptation measures and response options pertaining to water management in the mining industry.

Chapter 5: Conclusion

The mining industry's exposure to water-related risks a highlighted on Figure 2, is only expected to intensify over time as the global population grows, water demand increases and climate variability shifts hydrological patterns and changes average temperatures. As competing users demand higher volumes of limited water, mining companies will face more pressure related to their water access and use. Therefore this study aimed to examine how mining companies are planning to manage water risks, if at all, for periods of climate variability that may change with climate change in their mining operations.

Key research questions included

- How are mining companies currently dealing with climate risk in their management of water?
- Do mining companies have any future climate change adaptation plans for water management?
- Is it a national imperative to adaptively manage water in the extractive industry sector?
- Are there any barriers and opportunities that may constrain or facilitate effective climate change adaptation in the management of water?

The investigation was conducted using information from three sources: mining water policy documents (grouped here as governance), company reports and interviews. The finding of this study suggest that mining companies are not only dealing with current climate risks but they also using these risks to inform future adaptation measures,

Although mining companies appear to be adapting to climate variability in their management of water, there are some factors that could inhibit their adaptation progress. The outcomes of this study suggest there are 4 key factors that influence adaptive capacity from a South African mining company's perspective

- *Government and their engagement with mining companies.*

According to mining companies there is a poor business relationship and lack of collaboration with government bodies such as the DEA and DMR, in terms of water management in the face of climate variability. Respondents have acknowledged that the Chamber of mines has facilitated workshops and forums but the fall short with providing practical guidelines.

- *The uncertainty with climate variability and potential climatic impacts.*

  In addition to a range of associated risks shown in Table 2 and 3, climate variability and change have the potential to affect both short-term and long-term abundance of water resources (Schulze, 2011). Other potential risks include changes in annual hydrological patterns, humidity, temperature levels and wind intensity (DEA, 2013). Therefore water dependent sectors such as the mining industry are all the more vulnerable to the impacts associated with too much or too little water supply.

- *Mining regulatory requirements are becoming more stringent*

  The current state of the South African mining industry involves a lot of low quality ores. Ore bodies are changing as many mining sites have exhausted oxide based rocks and are currently mining sulphite based rocks. These types of ores are known to increase sulphate and nitrate generation, therefore the only modified processes to extract these ores are based heavily on water, and this becomes problematic because water use regulations are becoming more stringent.

- *Social adaptive capacity*
  The capacity for communities to adapt to climate variability is a major issue. Many companies are concerned that the potential vulnerability of many of communities to climate change has considerable regional significance because mining companies are often the dominant economic activity in these regions. Likewise the well-being of tertiary activities and local populations often depend on the viability of mining companies. In addition to this most communities' feel that their water is threated and mining companies are usually either competing or contamination the water resources. With climate variability, water scarcity or the incidence of flooding

could become more frequent and severe. Communities will be directly affected by this as they are in close proximity to mining operations.

The manner in which the South African mining industry responds to the challenges brought on by climate variability has important implications for the national economy and especially for widely dispersed regions across the country. Climate concerns are a central fact of business life and adapting to the reality of climate variability is in the best interests both of mining companies and communities whose well-being is intractably tied to the success of the industry. To date, the response to current and expected future climate variability has been slow, and where there has been response it has largely been the result of learning through experience.

The reluctance of the mining industry to take a pro-active stance on adaptation is largely the result of uncertainty about the emerging climate, but the scientific evidence persuasively suggests that some future climate variability is imminent. The South African landscape will be altered due to climate variability and there will be challenges for mining and other industries in the country.

Recommendations include mining companies collaborating with communities to increase social adaptive capacity through creating buffer zones between mining sites and residential areas, continuously maintaining rehabilitation programs, as well as participating in workshops, think tanks and platforms for information exchange. In shifting the agenda from the focus on mitigation to encompass adaptation as well, it must be recognized that the mining industry is a vital component of South African life. In the country, there are a number of mining companies operating at multiple locations and several associated structures (e.g. universities, research organizations, government offices). It is further recommended that multi-level co-operative partnerships need to be formed with the objective of working to advance the sector. Instead of waiting for government directive mining companies need to proactively and persistently engage with associated structures. The potential for cooperatively developing effective mitigation and adaptation strategies is thus substantial, and an area for further research.

Chapter 6: Appendix

6.1 Appendix 1: Interview questionnaire

Research Title: **Water management in the South African mining sector: the role of climate stress**

Questions to probe key areas of discussion: Mining companies

Theme 1: Introducing the participants' profession

1. What is your position in the company?

Probe- To identify the position the interviewee has and the experience they have within their respective department or field.

2. Describe the mandate and purpose of this department within the company and at which stage of the mining cycle is this department needed most?

Probe- To find out what role the department in which the interviewee works and to establish if they are part of the mining company from the planning stages.

Theme 2: Climate change awareness and considerations

3. What are some of the major current climate change risks that pose challenges to your mine?

Probe- To establish the extent of awareness of climate change.

4. How are climate change risks currently managed by the mining company?

Probe- To determine the type of management plans of climate change in mine planning throughout each stage of the mine cycle.

Theme 3: Adaptive management of water

5. What are some of the water risks that could potentially threaten mining operations (give a time frame)?

Probe- To verify the extent of awareness of water scarcity and fluctuating availability

6. Please describe any water risk management plans and strategies that the mine uses in mine operations?

Probe- To establish the existence and the type of water management plans or programmes (SEP, EMP or EMS).

7. Describe the stages of implementation of these management plans you have in place to manage water availability.

Probe- To determine the level of implementation of management's plans in mines throughout each stage of the mine cycle as well as integration into day to day operations.

8. When is the management plan revised or adjusted?

Probe-To identify the extent of considerations and actions taken to incorporate adaptive management and how often this takes place.

9. How often are regional and site-level scientific modelling exercises performed?

Probe- To determine the frequency of monitoring and reporting of physical risks and opportunities at the local level.

10. What are the major factors that influence your adaptive capacity to climate stresses? Please provide some opportunities and challenges.

Probe- To detect risks and feasibility issues associated with implementation of adaptive management.

Theme 4: Governance and collaboration

11. What external policy, regulations or guidelines do you have in place to assist with adaptive water management to climate stress?

Probe- To establish existence of any form of external guidance.

12. Describe how the company is integrating climate-related risks and adaptation measures into business decisions throughout the project lifecycle.

Probe- To identify level of integration and sustainability practices within company.

13. What type of cross-industry collaboration on regional adaptation strategies are being implemented?

Probe- To identify any form of collaborative efforts.

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