WATER CONSERVATION / WATER DEMAND MANAGEMENT IN THE SOUTH AFRICAN MINING INDUSTRY: A COMPENDIUM OF BEST PRACTICES AND CASE STUDIES

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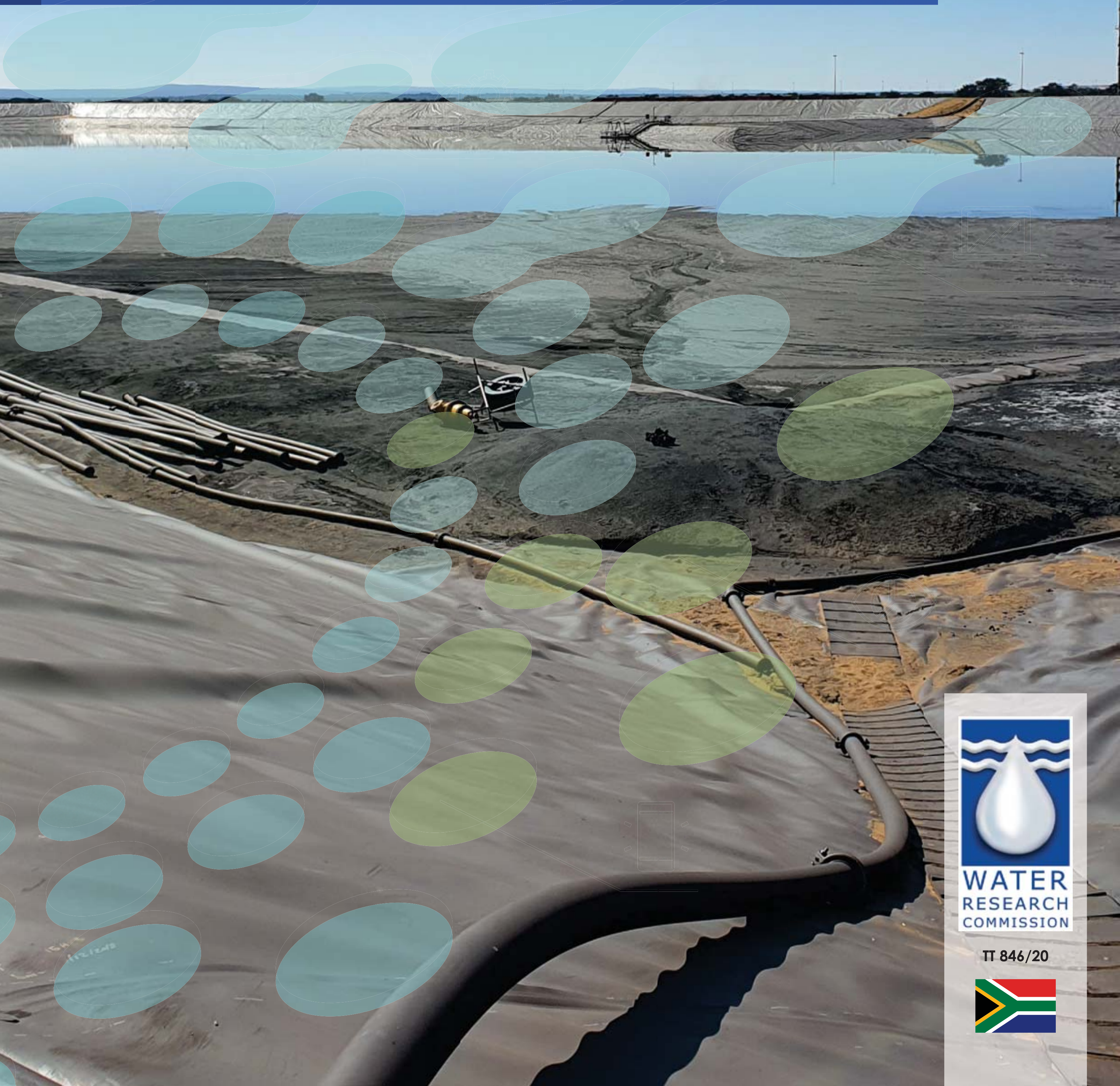

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Water Conservation / Water Demand Management in the South African Mining Industry: A Compendium of Best Practices and Case Studies

Report to the
Water Research Commission

by

P Moodley[1], N Juggath[1], Y Vemblanathan[1], MA Van Niekerk[1], Y Petersen[1], M Baloyi[1], W Pulles[2], David Love[1], Benita Aspeling[1]

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EXECUTIVE SUMMARY

BACKGROUND

Mining plays a significant role in the economy of South Africa, contributing to both the economy and employment. South Africa is a leading producer and supplier of a wide range of minerals, in particular gold, platinum-group metals (PGMs), diamonds, coal, iron ore and chrome. Water is a valuable resource and should be treated as such by the mining industry, especially in light of it being a shared resource within a catchment and security of supply will in the future be an important consideration. As a shared resource water can be a key part of providing support for the regional and community growth and development. This can only be done by the efficient use of water and consideration of Water Conservation / Water Demand Management (WC/WDM) considerations.

In terms of environmental footprint, the mining industry utilises approximately 3% of the total water withdrawn in South Africa and more so, is one of the main industries contributing to the deterioration of water quality in South Africa (Haggard et al., 2015). Water demand at a mine can be significantly reduced by using water more efficiently and with careful consideration and implementation of conservation and demand management measures, for example, the re-use and recycling of water. Water management strategies that incorporate the efficient use are key to reducing the demand for water in the mining sector.

AIMS AND OBJECTIVES OF THE PROJECT

The Water Research Commission (WRC) commissioned a project to compile a compendium of best practices and technological innovations in the mining industry with regards to Water Conservation / Water Demand Management. The specific aims of the project were:

1) To identify current best practice and technologies that could be implemented by the mining sector to improve its water use efficiency.

2) To identify promising developments and future opportunities that would lead to even more substantial improvements in water use efficiency through an examination of current developments or technologies being either researched or implemented.

3) To conduct site surveys on various mining commodities, such as coal, gold, platinum, etc., covering the mining extractive processes, ore processing or beneficiation, residue disposal and auxiliary/support services to identify and to document case studies and examples of best practice.

4) To develop a compendium of best practice in water efficiency technologies and approaches in the mining and mineral processing sectors that cover mining, beneficiation, residue disposal and auxiliary/support services.

CONCEPT OF WATER CONSERVATION / WATER DEMAND MANAGEMENT IN THE SOUTH AFRICAN CONTEXT

The concept of Water Conservation / Water Demand Management (WC/WDM) implies the minimisation of water loss or waste for the purpose of water use optimisation and efficient and effective use of water in an effort to manage (reduce) water demand, thereby protecting SA's scarce national water resources. WC/WDM is an integral component within SA's legislation and was re-enforced in the National Water Resource Strategy (NWRS) developed by the Department of Water and Sanitation (DWS).

South Africa is classified as a water scarce country, being the 30th driest in the world. The challenge for the South African mining sector is that this limited available water is distributed unevenly across the country, and rainfall varies dramatically from season to season. Furthermore, the mineral deposits, and therefore the mining operations, are generally situated in the more arid regions of the country where utilisable groundwater exploitation potential is also typically lower.

The National WC/WDM strategy provides a strategic approach to optimise the use of resources by focusing on the following developmental issues facing the country:

- Economic efficiency;
- Ecological sustainability; and
- Social equity.

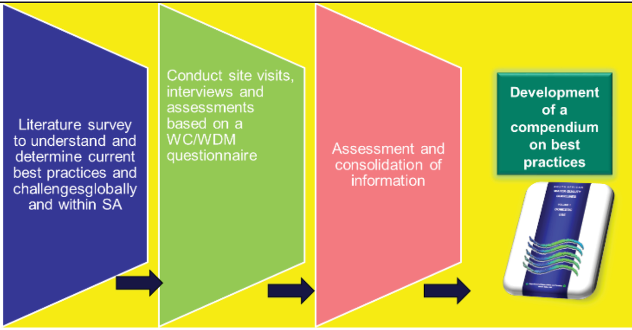
It is therefore imperative that WC/WDM is integrated into a mine's operations as a priority to alleviate the strain on the Nation's water resources.

The mining industry and other water uses across South Africa have been requesting authorisation and been granted authorisation to abstract and to use water from water resources, either surface or groundwater resources. The allocation of water is currently done based on a structured licensing approach adopted by the DWS, however there is little consideration with regards to whether water is being used efficiently by the specific applicant. There is currently no technical way for the Regulator to determine whether water use within a specific industry has been optimised to maximise the re-use and recycle of water before bringing in additional water into an operation. Existing designs can change. New designs must be implemented from start up. For new (greenfields) operations it becomes important to ensure that the design is based on, and incorporates water-efficient designs and technologies from the onset, such as the reuse and recycle of water. WC/WDM therefore is the reconciliation measure between the scarcity of water and water consumption and allocation within South Africa.

PROJECT APPROACH

The approach taken to deliver the objectives as stated above is briefly discussed below and presented in Table 1.

Table 1: Approach to the project

• Literature survey. • Review of Legislation. • Desktop assessments. • Site surveys; and • Data analysis and documentation.	

A literature survey was conducted with the following aims:

- To understand and determine current best practices and challenges globally and within SA.
- Learn from international experience on approaches, and
- Determine the rationale behind international best practice, guidelines and limitations.

A review of national and international legislation was conducted with the aim to:

- Consider any legal requirements nationally that is required to be met.
- Understand the regulatory framework and constraints within South Africa.
- Understand the regulatory framework of other countries and how it influences the implementation of water conservation measures, and
- Consider any legal requirements that need to be met.

Desktop assessments were conducted prior to site visits to establish a list of mines with WC/WDM initiatives where that require further investigations. Telephonic and email surveys were conducted via a pre-planned questionnaire and a project fact sheet (refer to Appendix C and D).

A desktop study was then conducted based on the current knowledge within the Golder and WRC database on existing mining operations within South and Southern Africa.

Site surveys to specific mines with promising WC/WDM initiatives were then visited to collect sufficient information to help build the case studies.

KEY FINDINGS

The key findings as a result of the project is that application of technologies and innovations within the mining industry in South Africa to conserve water and better manage the water demand is scarce. Most of the improvements in technology, if any, relate to revenue creation with a side benefit of water savings. Over the past few years this emphasis has shifted and companies are slowly realising the important impact water has on their operations and vice versa. Therefore, not many highly innovative or advances in technologies have been implemented successfully within the South African mining industry. A lot of the innovations and technology changes have occurred very recently without sufficient information and data to prove the success of the technologies. However, it must be noted that there is a definite shift in awareness with more and more initiatives and best practices being considered and implemented.

IMPLICATIONS OF FINDINGS

The implication of the findings is better knowledge sharing to the mining industry. The mining industry now possesses an arsenal of potential ideas that can be implemented at their operational sites to assist in the reduction of water demand and conservation of water.

CONCLUSION AND RECOMMENDATIONS

The project aim was successfully achieved. Some case studies of best practices and innovations are presented in the Compendium. Most mines were willing to share information on the best practices and innovations.

Due to the large number of mines within South Africa, it was difficult to cover all possible cases of best practices and innovation. The fast-paced environment of technology development and changes in water management strategies globally require a much longer time and resources to adequately cover the extent of the topic of innovations and best practices within the WC/WDM environment. This document, however, attempted to and successfully completed the objectives set out.

At the time of completion of the project some information was still outstanding which prevented the presentation of the case studies in the Compendium. A phase-2 study is recommended to allow for the collection of other case studies and best practices within the mining industry.

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

BPG	Best Practice Guidelines
CMS	Catchment Management Strategies
CoM	Chamber of Mines
DAF	Dissolved Air Flotation
DMS	Dense Medium Separation
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water & Sanitation
ESG	Environmental, Social and Governance
EWRP	eMalahleni Water Reclamation Plant
GAB	Great Artesian Basin
GAC	Granulated Activated Carbon
GMP	Genet Mineral Processing
ICMM	International Council of Mining and Metals
IX	Ion Exchange
MinCoSA	Minerals Council of South Africa *(previously COM)*
MPRDA	Minerals and Petroleum Resources Development Act of 2002
NEMA	National Environmental Management Act of 1998
NWA	National Water Act of 1998
NWC/WDMS	National Water Conservation and Water Demand Management Strategy
NWRS	National Water Resource Strategy
PGMs	Platinum Group Metals
RO	Reverse Osmosis
ROM	Run of Mine
SWAF	Standardised Water Accounting Framework
UF	Ultrafiltration
UGEP	Utilisable Groundwater Exploitation Potential
UN	United Nations
UNFCC	United Nations Framework Convention on Climate Change
WAF	Water Accounting Framework
WC	Water Conservation
WC/WDM	Water Conservation / Water Demand Management
WDM	Water Demand Management
WEF	World Economic Forum
WRC	Water Research Commission
WSA	The Water Services Act of 1997
WUE	Water Use Efficiency
WUL	Water Use Licence

GLOSSARY OF TERMS

Benchmark[1]: as used in this report, a benchmark is a value for an indicator that has been derived from an assessment of the status for the mining industry for that indicator at that time. The benchmark may be reported as an average value with an upper and lower limit, with the average value representing the average performance for the mines being assessed and the upper and lower limits representing one standard deviation. Benchmarks may be revised from time to time to represent the changing status of water use efficiency status of the indicator. Benchmarks do not inherently indicate best practice or the accepted level of performance for that indicator.

Beneficiation Plant[1]: a plant used at a mining site to beneficiate the mined ore to a product that is either sold to a client or sent for further processing in a pyrometallurgical plant.

Best practice[2]: commercial or professional procedures that are accepted or prescribed as being correct or most effective.

Calculated water inputs: Flows as calculated by the tool to allow the inputs and outputs to balance

Calculated water outputs: Flows calculated by the tool from input data to allow the inputs and outputs to balance

Consumptive water use outputs: All water outputs that can potentially be reduced to improve water use efficiency

Category 1: Water that can be re-used at the mine without treatment

Category 2: Water that can be re-used with simple treatment

Category 3: Water that may require extensive and costly treatment

Clean water: Natural water either from precipitation or other sources that does not come into contact with mine affected material such that the water meets the catchment specific Resource Water Quality Objectives and can be released into a specific catchment without any treatment.

Consumptive water use[1]: For the purpose of this report consumptive water use is defined as the total water use on the mine (including all water input sources) but excluding the water that is diverted around the mine's

[1] Definition as taken from, "*Benchmarks for Water Conservation / Water Demand Management in the Mining Sector*", DWS, 2016.
[2] Definition as taken from the Google, Merriam-Webster and Oxford dictionaries

operations without being used or affected by the operations and also excluding water that has been used in the mining operations and that is supplied directly to an off-site third party for beneficial use by that party.

Demand side management[1]**:** Any measure or initiative that will result in the reduction of the expected water use or water demand.

Dirty water: Natural water either from precipitation or other sources that comes into contact with mine affected material that renders contaminated such that it does not meet the catchment specific Resource Water Quality Objectives and therefore cannot be released into a specific catchment

Efficient Use of Water[1]**:** Water used for a specific purpose that is part of accepted and available best practices or water used for a purpose where benefit is derived from it (also referred to as water use efficiency). WUE can improve over time through the development and implementation of improved or new technologies.

FGX/FX process: Density based dry processing separation technology.

Indicator[1]**:** An indicator is a parameter that has been defined as being indicative of a mine's water use efficiency. These indicators are calculated using data from the mine's water balance and/or mining production rates.

Inefficient use of water[1]: Water used for a specific purpose over and above the accepted and available best practices and benchmarks or water used for a purpose where very little benefit is derived from it.

Mining area: The area or operations that specifically deals with the mining, collection or removal of valuable ore from the ground and stockpiling this ore to be processed elsewhere.

Mining operations: Operations, mining methodology or techniques that specifically refer to the act of collecting or removal of ore from the ground, such as by opencast or underground mining methods.

New water[1]**:** All water sources entering the mine water balance for the first time, therefore specifically excluding water that is recycled, reclaimed and/or reused by the mine. This could otherwise be defined as water required to replace water loss from the water circuit.

New water inputs: Water entering the overall water balance for the first time

Non-consumptive use[1]**:** Water that is utilised in open processes that generate wastewater and which can be recycled or discharged back into the water cycle for use by other users.

Non-consumptive water use outputs: All water outputs provided to off-site third parties for beneficial use and which are excluded from the consumptive water use indicators

Potable water: Water as defined by SANS 241 as water with a certain quality parameter limits that allows for the safe consumption by human beings.

Primary water use: Refers to the use of water that has not been altered in anyway by the mine, i.e. the use of new water that is introduced into the mine.

Ramsar Convention on Wetlands of International Importance especially as waterfowl habitat: An international treaty for the conservation of sustainable wetlands.

Recycled water: Refers to contaminated water that is re-used in the same process and has been treated in some way or the other prior to being re-used.

Recycled water inputs: Water recycled from other operations of the mine

Recycled water outputs: Water recycled to other operations on the mine

Resource Water Quality Objectives (RWQO): Objectives relating to the quality of the relevant water resources.

Retro fitting: The modification, adaptation or replacement of an existing device, fitting or appliance.

Re-use water: Refers to contaminated water that is re-directed to another part of the operation for use without treatment.

Run of mine (ROM) ore[1]: refers to ore in its natural, unprocessed state just as it is when delivered to the beneficiation plant and excludes waste material that is mined but not sent to the beneficiation plant. An ore is a type of rock that contains sufficient minerals with important elements including metals that can be economically extracted from the rock by beneficiation.

Secondary water use: Refers to the use of water that has either been recycled or re-used in the mine.

Standardised Water Accounting Framework (SWAF)[1]: a defined and prescriptive procedure/framework whereby the mine submits its WC/WDM plan (including water balance information, targets and management actions) and also submits its annual WC/WDM performance report for a defined period.

Support operations: Support operations includes admin offices, office areas, sewage treatment plants, central ablution areas and any other disturbed areas and water treatment plants not included under the mining, beneficiation and/or residue disposal areas

Targets[1]**:** Within the context of this report, a target is a mine-specific value for an indicator that is determined as part of the process of developing a WC/WDM plan as set out in the implementation guideline. Targets should be based on water use savings that each mine can achieve with its site-specific WC/WDM plan after implementing its selected management actions and should aim to fall below the indicator benchmark range determined for that commodity.

Water conservation[1]**:** The minimisation of loss or waste, the care and protection of water resources and the efficient and effective use of water.

Water demand[1]**:** The expected new water usage for a mine.

Water Demand Management[1]**:** The adaptation and implementation of a strategy by water institutions or consumers to influence the water demand and usage of water in order to meet any of the following objectives: economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services and political acceptability.

Water reclamation[1]**:** The treatment of water to make it suitable for use by an identified user.

Water recycling[1]**:** Involves only one use or user where the effluent resulting from the use is collected, treated (if necessary) and redirected back to its original use or related application. Water recycling sometimes involves the inclusion of additional treatment or a regeneration step to remove the contaminants that build up in the water being recycled.

Water reuse[1]**:** Utilisation of treated or untreated wastewater for a process other than the one that generated it, i.e. it involves a change of user. For instance, the re-use of municipal wastewater within mine beneficiation plant. Water re-use can be direct or indirect, intentional or unintentional, planned or unplanned, local, regional or national in terms of location, scale and significance. Water re-use may involve various kinds of treatment (or not) and the reclaimed water may be used for a variety of purposes.

WC/WDM Performance Report[1]**:** An annual on-line submission into the SWAF system whereby the mine reports on the mines updated water balance and progress towards meeting the targets as committed to in the WC/WDM Plan.

WC/WDM Plan[1]**:** a documented plan that presents the results of a process that a mine has undergone to develop a computerised water balance and site-specific indicator targets (volumetric and water use efficiency targets). This plan also includes specific management actions, budgets, schedules and responsibilities to meet those targets over the defined lifespan of the plan (typically 5 years). The plan may be in a written form and may be submitted in a summary form as required by the SWAF.

CHAPTER 1: BACKGROUND

1.1 INTRODUCTION

Water security is one of the most pressing global challenges of the 21st century. Cities are growing at an incredible pace around the world, increasing demand for secure supplies of food, water, and energy. Global water consumption has doubled every 20 years, and by 2025, at least two thirds of the world's population will likely be living in water stressed areas. These development pressures create many challenges for securing the long-term supply of water upon which people and nature depend. These concerns are further exacerbated by increasing climate variability, particularly in terms of its role in amplifying water-related natural disasters that threaten urban areas, agricultural production, and coastal populations (UN, 2016).

With consumption by the agriculture sector – which accounts for about 70% of water withdrawals worldwide – and industrial and energy production sectors forecast to increase significantly over the coming decades, coupled with accelerated urbanisation and associated increased municipal demand, ensuring water security has become a top priority for governments and multilateral organisations. The World Economic Forum (WEF) has since 2012 identified water shortage in its yearly 'Global Risks Report' as the third-greatest risk in terms of impact. For its part, the World Bank forecasts that water availability in cities could decline by up to two-thirds by 2050.

South Africa is amongst the 30th driest of 193 countries and having an estimated 1 110 m^3 of water per capita in 2005 (WRC, 2016). Further to this, the limited available water is distributed unevenly across the country, and rainfall varies dramatically from season to season, with extreme weather conditions and beset by both droughts and floods.

South Africa's water resources, already subjected to high hydro-climatic variability both over space and over time, are a key constraint to the country's continued economic development and the sustainable livelihoods of its people. Surface runoff is the main water source in South Africa. The average total mean annual runoff under natural (undeveloped) conditions is estimated at a little over 49 000 million m^3/a. This includes about 4 800 million m^3/a and 700 million m^3/a of water originating from Lesotho and Swaziland respectively, which naturally drains into South Africa.

South Africa receives only 490 mm/a of rainfall, about half the global average. It is classified as highly water stressed, with extreme climate and rainfall variability. Rainfall and river flows are seasonal and highly variable. As an indicator of the regional variability of the country's water supply, only about 20% of its land area produces 70% of all the runoff. Of the total rainfall, only 9% goes into rivers and surface water and 4% recharges the groundwater resource (Colvin et al., 2016).

Most of South Africa's key economic centres are located in areas of low water availability, resulting in local demand exceeding supply in many of the centres. However, the country has a highly integrated bulk water supply system that includes many large dams – the highest number in Africa – and many interbasin transfers to balance supply and demand. Thirty per cent of its towns and cities are experiencing a water deficit.

Figure 1 illustrates that mean annual precipitation is not evenly spread across South Africa, with the west coast and inland areas generally being more arid than the southern and eastern coastal areas. It is in these more arid areas that the majority of South Africa's mineral resources, and therefore the mining operations are situated.

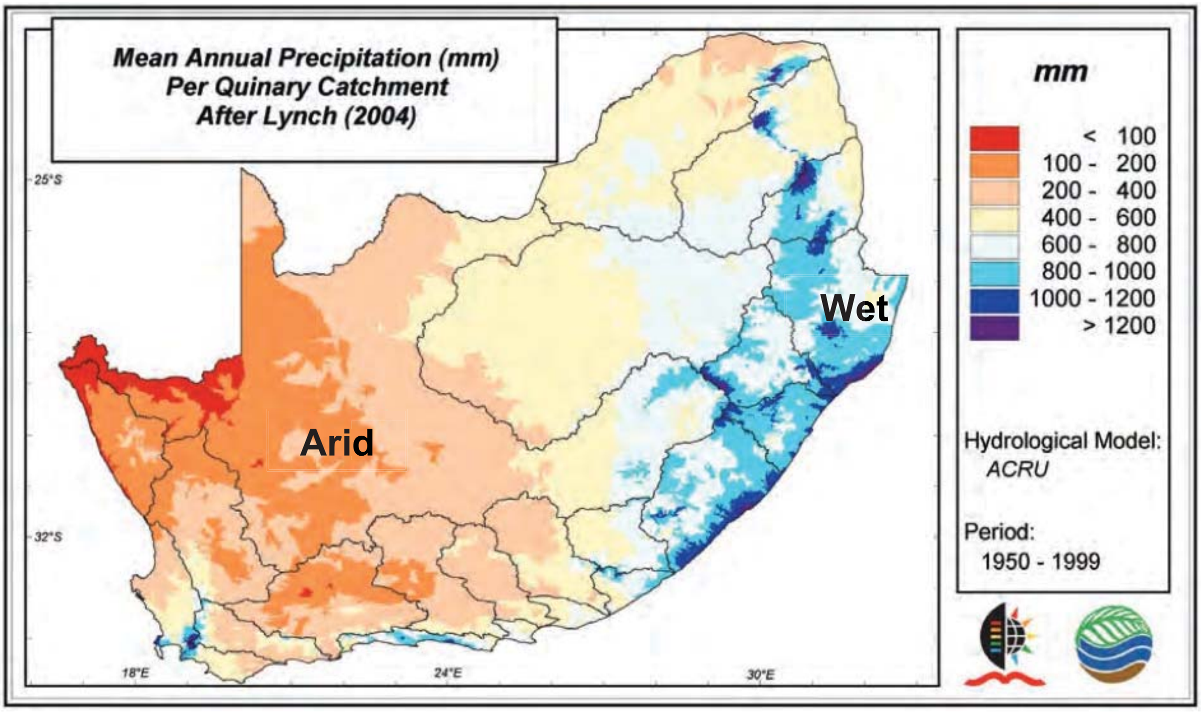

Figure 1: Evaporation and rainfall in South Africa (Shultze, 2011: 9)

South Africa has largely been reliant on surface (fresh) water and its development (DWS, 2013). However, based on the findings of recent water reconciliation studies, it is clear that surface water availability and its remaining development potential will be insufficient to support the growing economy and associated needs in full. Water development potential only exists in a few water management areas, whilst serious challenges remain in the majority of water management areas. To meet growing demands, South Africa will need to exploit alternative resources and improve water use efficiency.

Groundwater is also an important water source in South Africa, with a significant portion of the country's population depending on it for their domestic water needs. As a result, the value and vulnerability of groundwater represents a strategic component of water resources of South Africa. Security of groundwater supplies is thus essential and protection of groundwater has become a national priority. Thus, over abstraction and water pollution are serious problems in certain parts of South Africa.

As shown in Figure 2 below, Utilisable Groundwater Exploitation Potential (UGEP) is also note evenly spread across South Africa, with the west coast and inland areas generally having lower groundwater exploitation potential than the southern and eastern coastal areas. Similarly, with mean annual precipitation the majority of South Africa's mineral resources, and therefore the mining operations are situated in areas having lower groundwater exploitation potential.

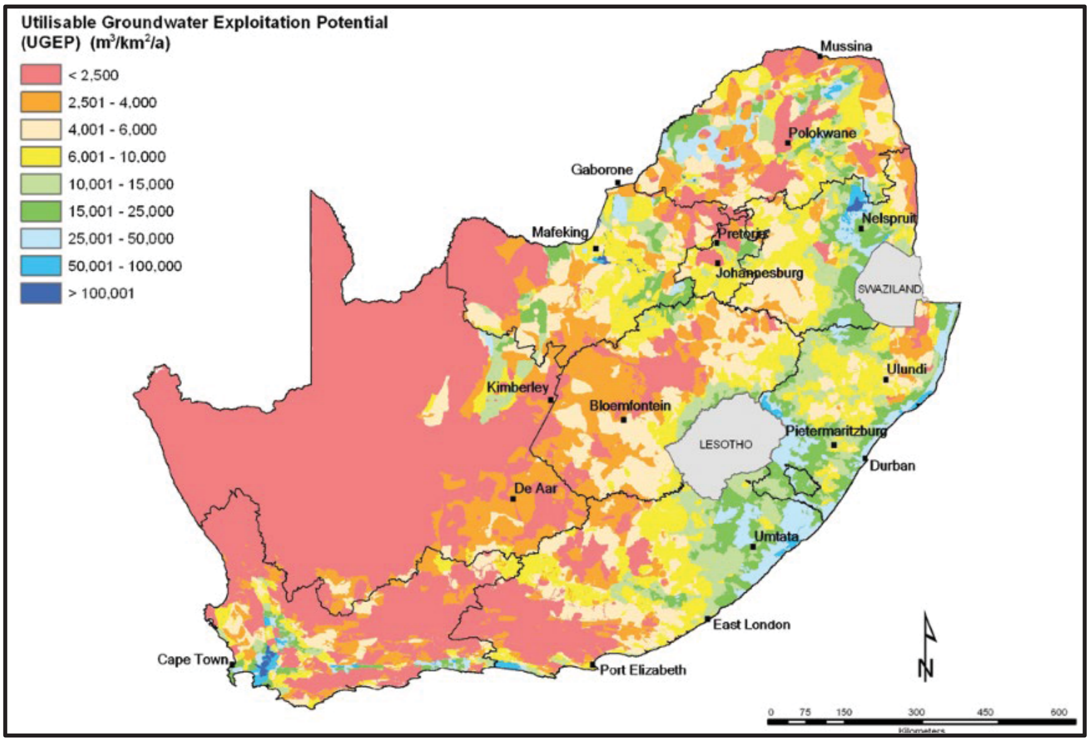

Figure 2: Utilisable Groundwater Exploitation Potential (DWA, 2010: 7)

Water quality and quantity in South Africa is under strain with increased urbanisation and a higher demand from both the industrial and domestic users. Several of the catchments within South Africa are water stressed.

The options for further augmentation and development of physical infrastructure are limited in South Africa. Attention in recent years has been on managing increasing demand for water in order to achieve a sustainable long-term balance between water availability and water requirements. Problems of water availability are now being addressed by appropriate mix of supply and demand side measures as seen in the various Water Reconciliation Strategies that have been developed by the Department of Water and Sanitation (DWS) for major catchment water resource systems in the country.

Water conservation and water demand management (WC/WDM) relates to the efficient and effective use of water and to the minimisation of loss and wastage of water and are important elements to the care and protection of water resources.

With the promulgation of the National Water Act (NWA) (Act No. 36 of 1998), a number of provisions and requirements relating directly or which refer to water conservation, have come to fore increasing the prominence and priority of WC/WDM as an essential component of water resource management. It is also intended to empower water users to understand the value of water as a scarce resource, and to adopt a responsible attitude and culture in its use. South Africa has focussed on all water use sectors, namely water services, agriculture and industry, mining and power (IMP) generation as part of the National WC/WDM strategy, as a means to increase water use efficiency and reduce the demand for water from already stressed water resources.

The wellbeing of the industry, mining and power generation sector is crucial to the economic development of South Africa and requires a high assurance of supply. The sector accounts for approximately 10% of the total water used (NWRS, 2013). Irrespective, there is scope for more efficient use of water without impacting adversely on economic activity. The sector is also a major source of water discharges into water resources.

The principle of WC/WDM allows for effective on-site water management to ensure water use optimisation thereby ensuring efficient water use, the conservation of water and a positive catchment water balanced. By practicing efficient water management, which includes measures such as re-use and recycle, reductions in water use can be achieved and sustained, resulting in water being made available to other water uses, either within the mining sector or for competing uses and for the Reserve.

All mines generally require a source of water supply, either in the mining process, as a feed into the mineral beneficiation process or for potable use. Giving the growing demand for water and its scarcity, it is important, but also responsible, for any mining operation to prove that water utilisation is optimised, including reuse and reclamation of contaminated water. It is therefore necessary that all mines implement WC/WDM measures in its processes, irrespective of the source of water (surface and/or ground) or whether there are downstream users within the catchment. The need for WC/WDM is further emphasised by the regional context of the particular mine, its impact on upstream and downstream users and benchmarking for the commodity sector in the mining industry.

1.2 PROJECT AIMS

In light of the issues raised in the introductory section, the WRC commissioned a project to understand how the concept of WC/WDM was being implemented in the mining industry. The aim of this project was therefore to:

1. Identify current best practice and technologies that could be implemented by the mining sector to improve its water use efficiency.
2. Identify promising developments and future opportunities that would lead to even more substantial improvements in water use efficiency through an examination of current developments or technologies being either researched or implemented.
3. Conduct site surveys on various mining commodities, such as coal, gold, platinum, etc. covering the mining extractive processes, ore processing or beneficiation, residue disposal and auxiliary/support services to identify and to document case studies and examples of best practice.

4. Develop a compendium of best practice in water efficiency technologies and approaches in the mining and mineral processing sectors that covers mining, beneficiation, residue disposal and auxiliary/support services.

1.3 BACKGROUND TO THE COMPENDIUM

This compendium has arisen out of a Water Research Commission (WRC) funded a project that has focused on a number of case studies on WC/WDM initiatives in the South African Mining Industry, with the intention of identifying innovations, practices and technologies that has resulted in efficient use of water and reduced water demand and water pollution. The initiative has been undertaken with the active participation and management involvement of both the DWS and a wide range of stakeholders from the mining sector to draw on the successes, lessons learnt and challenges encountered.

Application of best practices, principles, and procedures in an integrated manner, including re-use and recycling of water for example will have major benefits in reducing pollution as well as reducing water demand by South African mines thereby contributing to the goals of water use efficiency.

1.3.1 What is the compendium?

A compendium is a brief summary of a larger body of work or of a field of knowledge. This compendium documents WC/WDM best practices gained from the South African mining industry based on current mining activities and operations and new developments, for the purposes of knowledge sharing and promotion of adoption of the successes.

Best practice is defined as “a procedure that has been shown by research and experience to produce optimal or desired results and that is established or proposed as a standard suitable for widespread adoption.”

Currently, there is little guidance to those mines wishing to implement the principle of water use efficiency to be able to assess what WC/WDM initiatives or measures to implement to achieve the desired outcome, i.e. to identify the best practice that would best suit its operation and scenario context. Further to this, there are various ways to implement the identified WC/WDM initiatives that result not only in water savings but also long-term cost saving. The different measures, however, present as different outcomes on different mines and mining operations. To date, the successes achieved in implementation of WC/WDM initiatives in the mining sector in South Africa have not been formally investigated and recorded.

Therefore, this compendium fulfils the need to document the successful WC/WDM initiatives implemented and record the benefits achieved in order to share and disseminate the knowledge of the those practices and processes that yield the desired water use efficiency outcomes at various South African mines.

1.3.2 What does it include?

For the purposes of this endeavour, the compendium aims to show case examples of practices and process technologies within gold, coal, diamond and other ore mining operation that have yielded positive results for WC/WDM, in terms of the performance benchmarks and water balance audit.

The presented case studies highlight not only best practice in the industry, but also approaches that can potentially achieve greater effectiveness through improved management and implementation. The Compendium is aimed for use as a tool to identify, conceptualise, formulate and implement initiatives based on case studies presented that effectively address WC/WDM and reduce water wastage.

These are presented in a manner that may be easily adopted the mining industry within South Africa.

1.3.3 How was it developed?

A set of selection criteria was set in order to select which case studies should be prioritised for inclusion into the Compendium, namely:

- *Availability of information:* The extent and availability of information was an important part of selecting and compiling a case study.
- *Access to information:* The granting of permission to access and publish the information.
- *Extent of success of the activity:* Focus was given to operations that have achieved improved water use efficiency and water use reduction.
- *Intervention focus area representation:* A spread of a variety and representation of interventions documented as case studies across the different types of focus areas within the mining sector.
- *Diversity of the case study:* The diversity to the same type of intervention. Successful vs novel interventions with very little success.
- *Innovation of intervention:* Interventions that have viewed or found unique in addressing the WC/WDM concept.

1.3.4 What does it offer the user?

Best practices and successes that identify and evaluate a variety of site-specific appropriate water conservation measures that take account of the realities on an individual mining site are presented in the Compendium.

WC/WDM initiatives are presented in terms of three categories:

- strategies aimed at reducing mine water use,
- strategies aimed at reusing water (water reused without treatment) and
- strategies aimed at recycling water (treatment before reuse).

In all these instances, the net effect will be reduction of the amount of 1) Water being used and 2) Wastewater being discharged, disposed or lost from the mine water balance, e.g. by reusing it to replace other new water sources – based on recorded benefits achieved as follows:

a) current best practice and technologies to help deliver short, medium or long term, immediate or, incremental improvements in water efficiency through optimisation, retrofitting or re-designing existing assets and operations; and
b) identified promising developments and future opportunities to help deliver more substantial improvements in water use efficiency from the adoption of novel (but proven) technologies based on examination of current developments, research and implementation of best practice and new technologies.

The compendium shares positive WC/WDM practices aimed at encouraging mining businesses to adopt.

CHAPTER 2: WATER CONSERVATION AND WATER DEMAND MANAGEMENT IN SOUTH AFRICA

Since 1994 South Africa has moved from a water supply side management approach to also include a demand side management approach in order to holistically manage its scarce water resources. A key consideration given in the development of South African policies and strategies for water conservation and demand management is the scarcity of water. The adopted approach to water management is one that recognises the scarce nature of water in the region and focuses on using what is available as effectively as possible before searching for new supplies.

WC/WDM relates to the efficient and effective use of water and to minimise water loss and wastage. In addition, it also relates to the care and protection of water resources.

In South Africa, WC/WDM is guided by a sound legal and regulatory framework. The water law reform process, introduced a new direction and dimension to water resource management and the provision of water services in South Africa with the promulgation of the new water statutes, the National Water Act (Act No. 36 of 1998) (NWA) and the Water Services Act (Act No. 108 1997) (WSA). These statutes recognised the need for the development and implementation of water conservation and water demand management approaches to meet the fundamental principles of sustainability and equity through beneficial and efficient use. Emphasis has been placed on Integrated Water Resources Management (IWRM) to ensure environmental sustainability, socio-economic equity and efficiency in water use.

The DWS in implementing a legislative framework that promotes the efficient and sustainable use of water resources, has since then, undertaken the following activities:

- Taking a pioneering role in the integration of water conservation and water demand management in the behavioural processes and business culture of all sectors and spheres of South African society,
- Developed the National Water Conservation and Water Demand Management (NWC/WDM) Strategy in August 2004 to promote water as a primary, but scarce, resource that should be intrinsically valued,
- Initiated the National Water Conservation Strategy Framework (NWCSF) process in May 1999, which provided a solid foundation for the development of the four sectoral strategies, as well as defining eight strategic objectives upon which the sectoral strategies were based,
- Finalised sectoral Water Conservation and Water Demand Management Strategies in August 2004 for a) the Agriculture sector, b) the Industry, Power and Mining sector and c) the Water Services sector,
- Assisted with the development of an Integrated Water and Waste Management Plan (IWWMP) for the mining industry.
- Development of sector WC/WDM guidelines

The National WC/WDM Strategy was a fundamental step in promoting water use efficiency and is consistent with the NWA (Act No. 36 of 1998), which requires the conservation of water in its use and development.

The National WC/WDM Strategy is based on the three key principles:

- The efficient and effective supply of water services; that encompasses the minimisation of water losses and promotion of responsible behaviour among users and consumers.
- Efficient use of water (use that meets targets that goes beyond benchmarks for a particular purpose); and
- Incorporation of WC/WDM as an integral component of planning processes for water resource management (consideration of demand-side measures alongside supply side augmentation options).

A hierarchy for managing water conservation and demand management has been developed in 1991 and further in 2011, which requires the minimisation, re-use and recycling of all water with the discharge of water or wastewater as a last resort, thereby promulgating the optimal use of South Africa's scarce water resources. While this policy has been implemented over many decades, there is considerable scope for further implementation within the South African mining sector. All water use sectors are required to implement WC/WDM to promote efficiency and sustainable use.

The industry and mining sector utilise approximately 16% of the total water allocated in South Africa. It is therefore imperative that the concept of WC/WDM must be integrated into these operations as a priority and the focus should be on all sources of water (surface, ground, etc.).

While the policy and strategic framework for WC/WDM is available in South Africa, some challenges with regards to the pro-active implementation of WC/WDM in the industry and mining sectors exists. These challenges include:

- The cost of water is relatively cheap. As a result, there is limited monetary incentive to implement WC/WDM.
- Water issues are not incorporated into strategic business planning processes and are therefore not adequately assessed as part of the business risk.
- Water use efficiency targets are not incorporated into the performance targets of the responsible managers, and thus no direct accountability exists.
- Regulations for WC/WDM are currently lacking. However, over the past year or two, WC/WDM requirements have been stipulated in new Water Use Licences (WUL) that have been issued by the DWS.
- Lack of adequate enforcement and monitoring.
- Lack of understanding of correct implementation methodology.
- Poor uptake of proven water-efficient technologies especially by new mining developments (e.g. dry coal beneficiation), and unwillingness or financial constraints to retrofit existing operations.
- Lack of reporting by the sector on water use. In the cases where reporting does occur data deficiencies and inconsistencies in the manner in which many mines measure, review, manage and report on their water use is common.
- Inconsistency with regards to the reporting and modelling of water balances.
- Adoption of pollution abatement technologies as well as cleaner production technologies is not a priority. As a result, most mines still relying on the end of pipe treatment options.

- Water issues are not incorporated into strategic business planning processes and therefore these issues are not adequately resolved;
- Lack of WC/WDM culture within the mining company. This ties in with the previous point where water issues are not incorporated into strategic business processes. Water issues, specifically WC/WDM should be incorporated into staff and contractor training.

In addressing the challenges related to implementation and practice of WC/WDM, the DWS working in collaboration with the Chamber of Mines (COM) commissioned a project to undertake the “Setting of Water Conservation and Water Demand Management targets in the South African Mining Sector”.
The outcomes of the project was the development of the following documentation:

- Guideline for the Development and Implementation of Water Conservation / Water Demand Management Plans for the Mining Sector, DWS, 2016
- Benchmarks for Water Conservation / Water Demand Management in the Mining Sector, DWS, 2016
- Best Practice Guideline G6: Standardised Water Accounting Framework, DWS, 2017

A framework guideline was prepared in 2006 and published by the DWS. The need for a practical implementation methodology for WC/WDM to assist in reporting, tracking, recording and enforcing water use in the mining industry was identified.

CHAPTER 3: GENERIC WC/WDM MINE WATER MODEL

3.1 INTRODUCTION

Figure 3: Simplified mine water balance

Figure 3 represents a simplified mine water balance and Figure 4 presents a generic mine water reticulation diagram showing different operational areas. The different operational areas of a mine include:

- The Mining operations, which may consist of surface and / or underground mining operations;
    - Underground mining – generates water from ingress from groundwater aquifer's (as a result of rain recharge through shafts and fissures) requiring underground dewatering to a water storage facility.
    - Open pit – generates water from opencast collection via groundwater ingress, direct rainfall, rain recharge and runoff requiring dewatering of the mine workings.
- Beneficiation plant – generates water from process water circuits;
- Residue Disposal, which may include coarse disposal, fines disposal and waste rock/discard disposal – water generated from residue management circuits; and
- Support operations.

All these areas will include the following that either forms a source of water into the mine's water balance or a use of water:

- Surface / stormwater runoff – which generates water from surface catchments and river diversions;
- Water utilities – which refers to incoming water, potable water, cooling, wash/sanitation circuits, etc.
- Environmental water – which refers to dust suppression, rehabilitation, land restorations, etc.

3.2 APPLICATION AND USE OF WATER IN A MINE

Mining uses water primarily for mineral processing, dust suppression, slurry transport and employees' needs. In most mining operations, water is sought from groundwater, streams, rivers and lakes, or through commercial water service suppliers. But often, mine sites are located in areas where water is already scarce and, understandably, local communities and authorities often oppose mines using water from these sources.

The beneficial use of water includes:

- Mining, hydraulic transport of materials;
- Mineral processing;
- Dust suppression, environmental rehabilitation;
- Drinking water;
- Some contractual obligations to supply water to a third party; and
- Water supply to projects.

Figure 5 shows some recommended practices that can be implemented on a mine site. These will be discussed in more detail in the sections that follow. Measures to reduce mine water are shown in Table 2. Measures are categorised as:

- Measures to reduce mine water use;
- Measures to re-use mine water; and
- Measures to re-cycle mine water.

Table 2: Reduction of Mine water use

At Mining Operations
Include an adequate / comprehensive network of flow meters.
Implement a data storage system to store flow, level water quality and production data.
Mine planning to consider avoiding the intersection / interconnection to water-bearing strata / aquifers.
Where intersection / interconnection with water bearing strata/aquifers is unavoidable, dewater prior to water quality deterioration.
Mine planning done to avoid surface water bodies such as streams, wetlands and dams.
Old workings and shafts sealed off to prevent ingress into active workings.
Diversion of surface water streams around mining areas to limit ingress.
Optimisation of ventilation to reduce the cooling / refrigeration requirement.
Backfill underground workings to reduce water ingress and cooling requirements. Water quality aspects are an important consideration here.
Separate and divert surface water (rainfall, runoff), which may enter the opencast pit workings.
Conduct concurrent rehabilitation of opencast and open pit workings. This will reduce the total amount of contaminated runoff that reports to the pits. In addition, in coal mines, this will control the spontaneous combustion and the formation of hot spots.
Rehabilitated opencast and open pit workings by implementing cover material that will reduce recharge/ingress.
Backfill and rehabilitate final voids to reduce evaporation. Prevent erosion by revegetation, compaction, and reshaping to a lower gradient as possible and to ensure free draining.
Reducing evaporation through covers and through alternative dust suppressants.
Ensuring no unplanned pipeline water losses.
Reduce the operational surface footprint of the mine, e.g. smaller shaft areas, minimal spoils piles, less roads, compact plant design.
Reduce the contaminated catchment area of pollution control dams.
Ensure adequately sized and properly designed pollution control and return water dams. Ensure that the design allows for seepage control and designed to minimise flooding.
Reduce the dust suppression area required.
Utilise dust suppressants where applicable.
Employ dry cooling systems on underground mine workings / refrigeration circuits, rather than evaporative cooling.
Use dust filters rather than dust sprays to control underground air quality.
Minimise contact time between water and ore in the mining operations in order to reduce water quality deterioration. This will decrease the treatment requirements and enable easier use of the water with minimal treatment. This will also improve mining extraction efficiency to reduce residual exposed minerals (e.g. sulphides) and assist in preventing ARD and spontaneous combustion as well as in optimising stooping

Employ leak detection systems on pipelines and dams.
Include level measurements on dams.
Include level control on dams to pump out and prevent spillages.
Conduct regular surveys of voids and other water storage facilities to confirm level and capacity.
Store water in underground compartments to reduce evaporative losses but ensure that proper pollution control is implemented (e.g. by using lime, linings, etc. to prevent the generation of acid rock drainage).
Employ aquifer recharge and abstraction to reduce evaporative losses. Ensure that control ARD and pollution is implemented and that the required licenses and permits with respect to the NWA are in place.
Ore quantity reduction for processing. Reducing the amount of ore sent to the mill (e.g. by the implementation of effective grade control/ore sorting) can reduce the amount of water required for processing, cooling water required and the corresponding evaporation and water retained in the tailings
Dust suppression alternatives to water can be used. This includes salts, surfactants, soil cements, bitumen's and films can reduce water consumption. Using organic binders to harden road surfaces can achieve water savings of 67% to 90%. Use of asphalt or chemical stabilisers on roads
Man-made aquifers: Artificial aquifers can be developed using existing backfilled mining voids. Raw water is then stored in these voids and extracted to use in the water treatment plants. These aquifers could increase assurance of supply, effective storage of water with minimum evaporation and environmental losses and decrease dirty water discharge.
Storage capacities: Based on water balance simulation, design appropriate balancing storage capacity (surface or underground for each shaft) to eliminate discharges. Ensure that the appropriate design flood parameters are applied.
Pollution prevention plans: Develop detailed understanding of sources of WQ deterioration in underground mines and develop pollution prevention plan to manage flooding of mines in a way to protect mine water quality.
Underground mining operations to serve as conduits: Evaluate potential of underground mining operations to serve as conduits for moving water and for storing water in manner with zero seepage and evaporation losses (only if WQ evolution is understood)
Water ingress into mine workings: Intercept shallow ingress of water into mine workings through dewatering boreholes and implement surface water diversion.
Reduction of abstraction methods: The rate of abstraction can be reduced by optimizing water recovery and recycling and by substituting poor-quality local groundwater in some areas.
Stormwater management systems: Implement storm water management systems at every shaft.
Pipeline losses Where possible, pipelines should be repaired to avoid leaks and unplanned water losses
At Beneficiation
Include an adequate / comprehensive network of flow meters.
Ensure effective maintenance of meters and recording measurements

Implement a data storage system to store flow, level water quality and production data.
Reducing excessive fines (clay) generation during grinding to lower tailings water retention. This can be accomplished by optimising grinding techniques.
Improving tailings thickener performance and water recovery, e.g. by the utilisation of flocculants and efficient thickener operation (e.g. by density control of underflow).
Reducing water losses through thickened tailings or paste tailings disposal
Solid / liquid separation prior to disposal of tailings, e.g. cycloning and filtration (Larox filters).
Reducing water losses through tailings compaction
Reducing water losses through selective tailings size classification
Reducing water losses by using tailings filtration
Reducing the concentrate moisture content, e.g. by thickening / clarification by the use of high rate /lamellar thickeners/clarifiers) and filtration (e.g. disk filters or filter presses)
Increasing solids density: Increasing the solids density of the thickener underflow can reduce the amount of water pumped back to the TSF. Pumping can be done by the means of peristaltic pumps, e.g.
Filtered tailings
Dry processing technology: An extreme option to reduce water consumption would be too implement more dry processes or an entirely dry processing plant. Consideration for dust generation and suppression must be given
Use dry conveyance methodologies (conveyor belts rather than slurry pipelines). Enclosed conveyors such as Japanese pipe conveyors can be considered
Reducing evaporation through covers
Reducing evaporation through alternative dust suppressants
Ensuring no unplanned pipeline water losses
Eliminating evaporative cooling and use dry cooling technologies rather.
Reducing pump surface water usage
Reducing water consumption through ore pre-concentration
Reducing water use through dry processing.
Reduce fines component in the plant. Fines typically retain more water.
Employ leak detection systems on pipelines and dams.
Reducing evaporation through covers.
Ensuring no unplanned pipeline water losses.
Reduce the operational surface footprint of the plant and other contaminated catchments.
Reduce the footprint of the ROM, products and waste stockpiles with due consideration of corrosion, dust and the requirements for vegetation and access if required
Place product stockpiles under dry covers so that they shed water and do not collect and contaminate storm water that would require collection afterwards.
Use appropriate cut-off/drainage trenches and management of runoff as appropriate
Reduce the contaminated catchment area of pollution control dams.
Ensure adequately sized pollution control and return water dams.

Include level measurements on dams.
Include level control on dams to pump out and prevent spillages.
Conduct dry wash down and spillage clean-up by utilising alternate mediums.
Capture all spills as close as possible to the point of origin of the spillage and reuse elsewhere.
Separate storm water and process water system to allow for optimal re-use or storage of less contaminated water. This also allows for collection of process spillages closer to the origin to allow for direct reuse.
In line with the above initiative, water usage should be optimised with respect to water quality requirements. Minimise the use of potable water where possible and substitute with water treated to the required level.
Ore quantity reduction for processing: Reducing the amount of ore sent to the mill can reduce the amount of water required for processing, cooling water required and the corresponding evaporation and water retained in the tailings.
Management of spillages: All spillages in Processing Plants are to be captured and channelled to a large recycle sump for re-use.
Ore pre-concentration: Dense media separation or sorting technologies can be used to pre concentrate ore at coarser particle sizes.
Water entrainment: Water entrained in the tailings can be reduced by a number of methods including lowering the amount of fines generated during processing, monitoring of waste storage facilities and taking appropriate action to prevent ARD, leaching of wastes and TSF failures (prevent pollution, siltation and flooding)
Reduce evaporation at tailings facilities: Floating covers can be placed on open water in tailings facilities in addition to covering water storage tanks and thickeners.
Floating plastic balls can be implemented at these facilities.
Install drains underneath the TSF and compact tailing through co-disposal with waste rock or even explosives.
Dust suppression: The introduction of dust suppression alternatives such as salts, surfactants, soil cements, bitumen’s and films can reduce water consumption. Using organic binders to harden road surfaces can achieve water savings of 67% to 90%. Use of asphalt or chemical stabilisers on roads
Use of vegetation for dust suppression and stabilisation
Paste and thickened tailings: The installation of a paste and thickened tailings disposal component at the existing combined treatment plant to improve water recovery from the tailings. This component allows for maximum recovery of water for reuse onsite.
Modular systems: Implementation of modular systems, which would allow expansion of the plant over several years as the population grows. This could also allow for more effective design as the plant would need to be changed.
Mine water eco-efficiency: Installation of specialised thickeners which allows for 7 to 10 times reuse of water before discharge is required.
Improve process efficiency to reduce spillages and flooding and reduce valuable (potential contaminants) from being disposed of or stored as waste

Reducing evaporation – existing sprinkler systems can be replaced with a more advanced and water-efficient drip-feed system and impermeable plastic covers can also be installed over the areas of the leach pads being irrigated to reduce evaporation.
Increasing the solids density of the thickener underflow can reduce the amount of water sent to the TSF thus potentially reducing the amount of water lost to evaporation, retention or seepage.
Complete construction of scavenging boreholes into lined solution trenches
Evaporative systems Continue converting to closed evaporative cooling systems
Cooling water from various locations such as equipment, acid plants, laboratories, thermoelectric plants and others should be recirculated – after treatment if necessary.
Pipeline losses: Where possible, pipelines should be repaired to avoid leaks and unplanned water losses.
Heap leach construction may be enhanced by using drip irrigation to reduce evaporation and construction of drains (basal, intermediate and pipes)
Automation of plant processes
Construction of thickeners at heights greater than normal (45 to 60ft) results in a slurry (pulp) that is of a higher density (65-75%) which increases the concentration in the weight of the tailings by about 8% as compared to conventional high efficiency thickeners (which typically save 15% water)
Residue Disposal
Include an adequate / comprehensive network of flow meters.
Implement a data storage system to store flow, level water quality and production data.
Reducing wet area/open area in the TSF
Reducing water losses through the installation of drains in the TSF.
Thicken and/or dewater residues and tailings to limit the amount of water disposed with the residues and tailings that is then lost through evaporation and/or seepage. (high density thickeners and pressure filters
Reduce the amount of water stored on the residue/tailings disposal facilities in order to reduce evaporative losses. Design the surface area of the free water pool on tailings storage facilities for minimal surface areas to reduce evaporative losses. ○ Tailings water loss reduction ○ Install drains underneath the TSF
Compact tailing through co-disposal with waste rock or even explosives.
Proper design and placement of waste storage facilities to prevent erosion, TSF failures and pollution
Collect and intercept seepage for reuse and recycle.
Ensure adequately sized and operated return water dams.
Dispose of waste in underground workings (backfill) to reduce the surface footprint of waste/residue disposal facilities and hence the volume of storm water contaminated.

Dispose of waste in old opencast and pit workings to reduce the surface footprint of waste/residue disposal facilities (caution with regards to water quality): • Less surface area for storm water contamination • Assists with the free drainage of the pit once rehabilitated and hence the reduced ingress of water into the pit itself • Reduces the contamination of the perched aquifer One needs to ensure that potential contaminants are minimised/eliminated
Reducing evaporation through covers
Reducing evaporation through alternative dust suppressants
Ensuring no unplanned pipeline water losses.
Reduce the contaminated catchment area of pollution control dams.
Ensure adequately sized pollution control and return water dams.
Include level measurements on dams.
Include level control on dams to pump out and prevent spillages.
Significant water savings: Significant water savings can be achieved by reducing the available wet/and or open water area which can be done by carefully managing the placement of tailings.
Dust suppression: The introduction of dust suppression alternatives such as salts, surfactants, soil cements, bitumen's and films can reduce water consumption. Using organic binders to harden road surfaces can achieve water savings of 67% to 90%. Use of asphalt or chemical stabilisers on roads
Complete construction of scavenging boreholes into lined solution trenches
Evaporative systems
Pipeline losses
Recirculation from tailings impoundments can be improved by designing to get better recovery (largest losses occur because of evaporation, infiltration and retention), covering the bottom of the impoundments with a geosynthetic liner or other fine material to decrease its permeability, installing a basin drain (to reduce filtration), and filtering the tailings.
Place tailings upslope from the free water surface in the impoundments to minimise seepage
Install intercept wells downgradient of the TSF to capture seepage
Create "stilling basins" so that their surface area is minimised to reduce water loss by evaporation. Stilling basins are areas of free-standing water that are formed in tailings impoundments when the tailings are deposited and settle out
Cover or cap abandoned tailings impoundments to reduce water for dust control
Support Operation
Include an adequate / comprehensive network of flow meters.
Implement a data storage system to store flow, level water quality and production data.
Reducing evaporation through covers
Reducing evaporation through alternative dust suppressants
Ensuring no unplanned pipeline water losses
Reducing site employee/contractor water use.
Reduce the contaminated catchment area of pollution control dams.

Ensure adequately sized pollution control and return water dams.
Include level measurements on dams.
Include level control on dams to pump out and prevent spillages.
Dust suppression: The introduction of dust suppression alternatives such as salts, surfactants, soil cements, bitumen’s and films can reduce water consumption. Using organic binders to harden road surfaces can achieve water savings of 67% to 90%. Use of asphalt or chemical stabilisers on roads
Greywater usage: Grey water can be used from the local municipal sewage system in the mining operations and added to the processes as make-up water. Greywater can also be captured from showers or toilets for watering green spaces around the site.
Ablution facilities water saving measures: Low water showers and low or zero water toilets can be introduced.
Complete construction of scavenging boreholes into lined solution trenches
Evaporative systems
Pipeline losses
Water reclamation: Treated water from the plant can be added to local municipality drinking water supply system.
Xeroscape landscape
Utilise drought-tolerant plants when revegetating abandoned mine land
Use of alternative sources of water instead of groundwater, river or dam water – potable and municipal
Greywater usage: Grey water can be used from the local municipal sewage system in the mining operations and added to the processes as make-up water. Greywater can also be captured from showers or toilets for watering green spaces around the site.

Efforts to ***reuse*** mine water are shown in **Table 3**.

Table 3: Reuse of Mine water

Mining Operations
Collecting and reusing surface runoff water via dewatering of pit
Reusing mine dewatering water
Dewatering of the underground mine and from the surface pit operation provides additional water that is collected and stored in the dams for re-use and/or recycle.
Beneficiation
Collecting and reusing surface runoff water
Reusing cooling water
Reusing water recovered from ore and minerals products.
Reusing water recovered from waste and tailings.
Residual Disposals
Collecting and reusing surface runoff water
Support Operations
Collecting and reusing surface runoff water
Reusing grey water

Efforts to ***reduce*** mine water are shown in Table 4.

Table 4: Recycle of Mine water

Mining operations
Recycling potential mine effluent water
Treating mine water that has been extracted prior to be exposed to the ore and therefore requires minimal treatment before re-use
Beneficiation
Recycling tailings thickener overflow
Recycling concentrate or intermediate thickener overflow
Residue Disposal
Recycling TSF surface water
Recycling TSF seepage water
Support Operations
Collecting and reusing surface runoff water
Reusing grey water

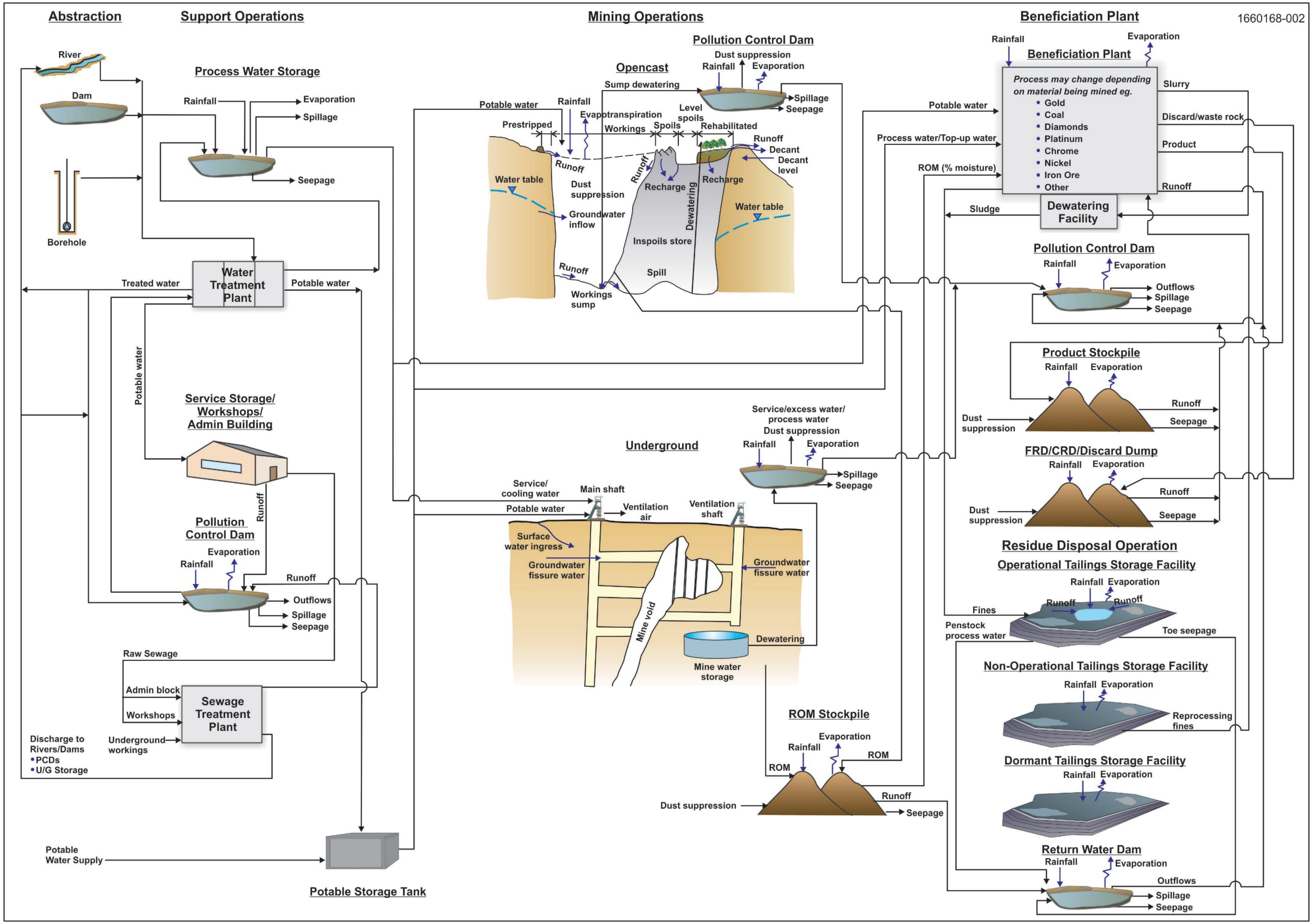

Figure 4: Generic mine water reticulation diagram

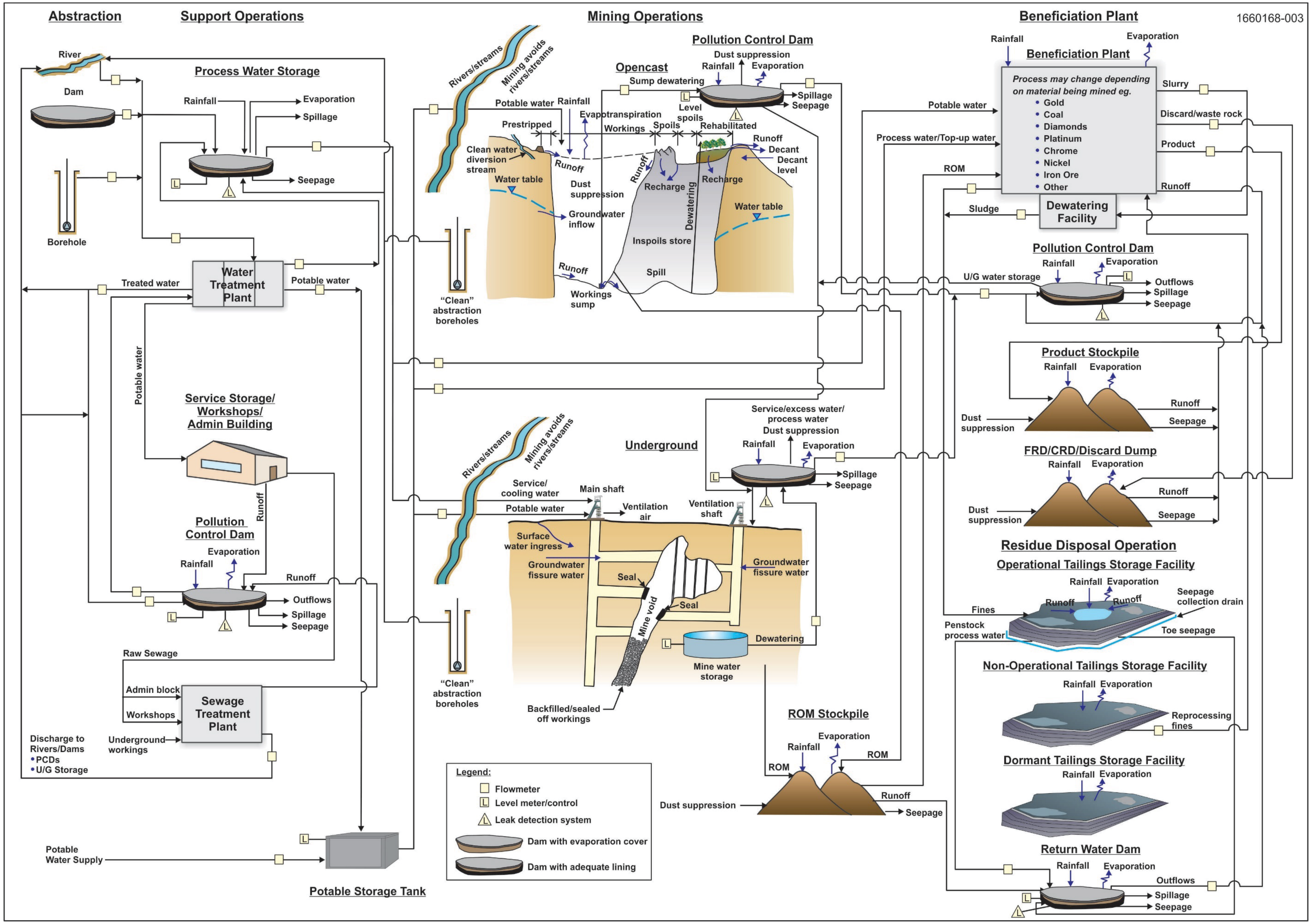

Figure 5: Some WC/WDM interventions on a typical mine site-wide reticulation diagram

CHAPTER 4: ACTUAL WC/WDM PERFORMANCE FOR MINES WITHIN SOUTH AFRICA

4.1 INTRODUCTION

Water use efficiency (WUE) indicators were computed for some mines. These values are presented per commodity, coal, gold, platinum, diamond and other, in Table 5 to Table 9 respectively. The values in the tables are discussed in the sub-sections that follow and represent the most recent data that was provided to Golder.

4.2 CALCULATION METHODOLOGY

The calculation methodology adopted to determine WUE indicators for the various operations is discussed below. This is based on the recommended methodology from the WC/WDM guideline document as published by the DWS in 2016 (DWS, 2016b).

4.2.1 DWS recommended guideline methodology

The WC/WDM best practice guideline, (DWS, 2016b), provides a systematic way in which WC/WDM can be implemented (Figure 6). The key principles required to be incorporated in a WC/WDM plan according to DWS, 2016a are:

- An accurate, reliable and dynamic water balance model with predictive and probabilistic capabilities.
- The development of the WC/WDM plan is to be done in phases to ensure key decision points are afforded the correct amount of focus to move onto subsequent phases.
- Optimum improvement should be achieved as soon as possible.
- The cost implications associated with the plan must be understood and financial commitments should be taken by correct management levels.
- The WC/WDM plan must be practical and implementable. No benefit can be achieved from a plan with minimal improvement or from an ambitious plan with inadequate information and planning. The Plan should be integrated with Operations Management, Environmental Management and Corporate / Environmental Governance.

4.2.1.1 WC/WDM Methodology

The methodology that is recommended to be used is a phased stepwise approach as illustrated in Figure 6 and is summarised as follows:

- Step 1 – Calculation of current WUE indicators;
    - Ensure accurate, dynamic and predictive water balance exists that integrates all site operations. The use if a dynamic probabilistic water balance model that can also be utilised where appropriate when plant modifications are considered is recommended.

    - Identify potential WC/WDM measures – compare the calculated WUE indicators with the pre-determine industry target values to identify improvement areas
- Step 2 – Simulate each WC/WDM measure to determine improved WUE indicators.
- Step 3 – Rate and rank WC/WDM measures to select the most viable and cost-effective measures for implementation as part of a 5-year WC/WDM plan; and
- Step 4 – Submit WC/WDM results on an annual basis to the DWS via online system.

4.2.1.2 Water use indicators

Key indicators have been determined to allow for the evaluation of the mine's WC/WDM performance. These indicators have been agreed to by all relevant parties be imperative in terms of WC/WDM for a mine. These indicators are determined using a generic water balance that is applied for the site engagements. There is a total of seven indicators, three of the seven represent volumetric indicators and four represent efficiency indicators. Refer to Figure 7 for a flow diagram that illustrates the calculation of these indicators.

The key indicators can be applied to the total mine (and all operations associated with the mine), as well as to individual mining operations (e.g. mining, beneficiation and residue disposal), refer to Figure 8 for the consolidated mine WC/WDM evaluation. These indicators are listed and discussed below.

Volumetric indicators

- Total water use (volume – m^3/day or kl/day)
- Consumptive water use (volume – m^3/day or kl/day)
- Volume of wastewater lost from the mine operations, including all point and diffuse discharges to surface and/or ground water, seepage, evaporation (including from dust suppression) and unaccounted for water, but excluding water used for direct human consumption, surface moisture on product and moisture retained within mine residues – interstitial water (reported as a volume – m^3/day or kl/day).

Efficiency indicators

- Total specific water use – total water use per production measure (m^3 per ton of run of mine (ROM) ore)
- Consumptive specific water use – consumptive water use per production measure (m^3 per ton of ROM ore)
- Percentage of wastewater not recycled or reused – calculated as the volume of wastewater lost from the operations divided by the sum of the consumptive water use plus the recycled/reused water (%).
- Water recycling ratio (all recycle and reuse streams added together and reported as a percentage of total water use plus recycle/reuse volumes) (%)

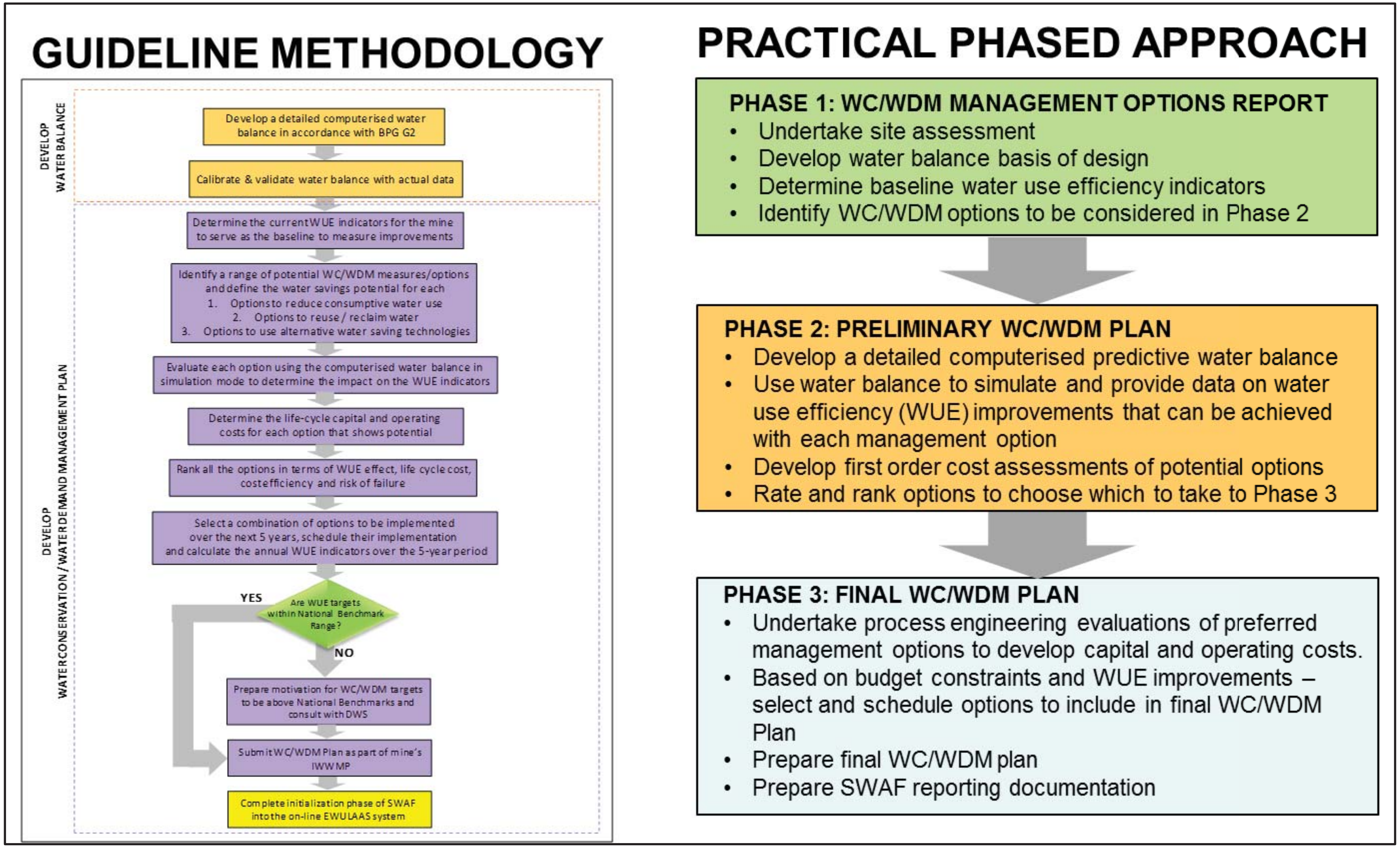

Figure 6: Recommended practical phased approach for the implementation of WC/WDM (DWS, 2016b)

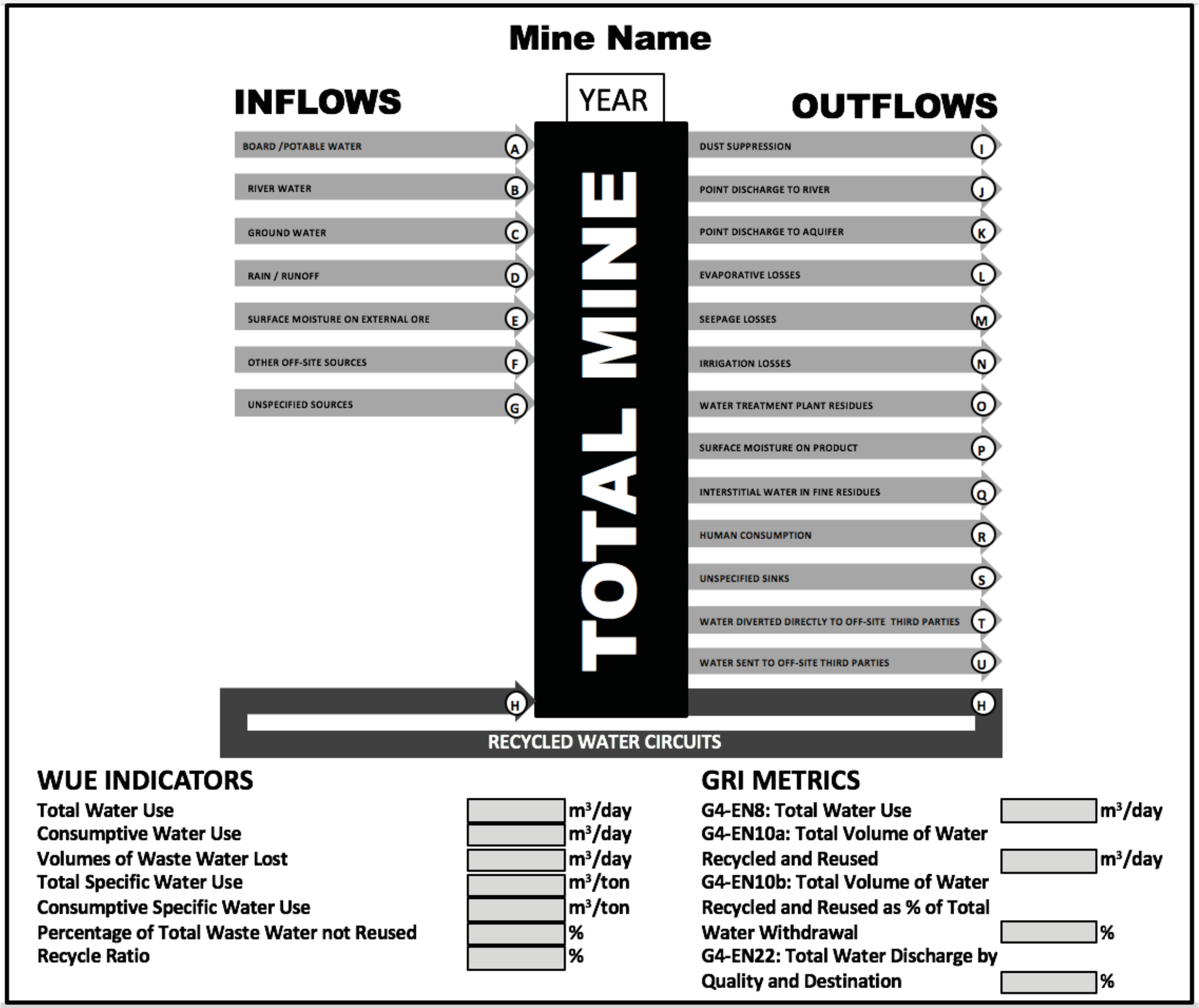

Figure 7: Flow diagram to illustrating the calculation of WUE indicators (DWS, 2016b)

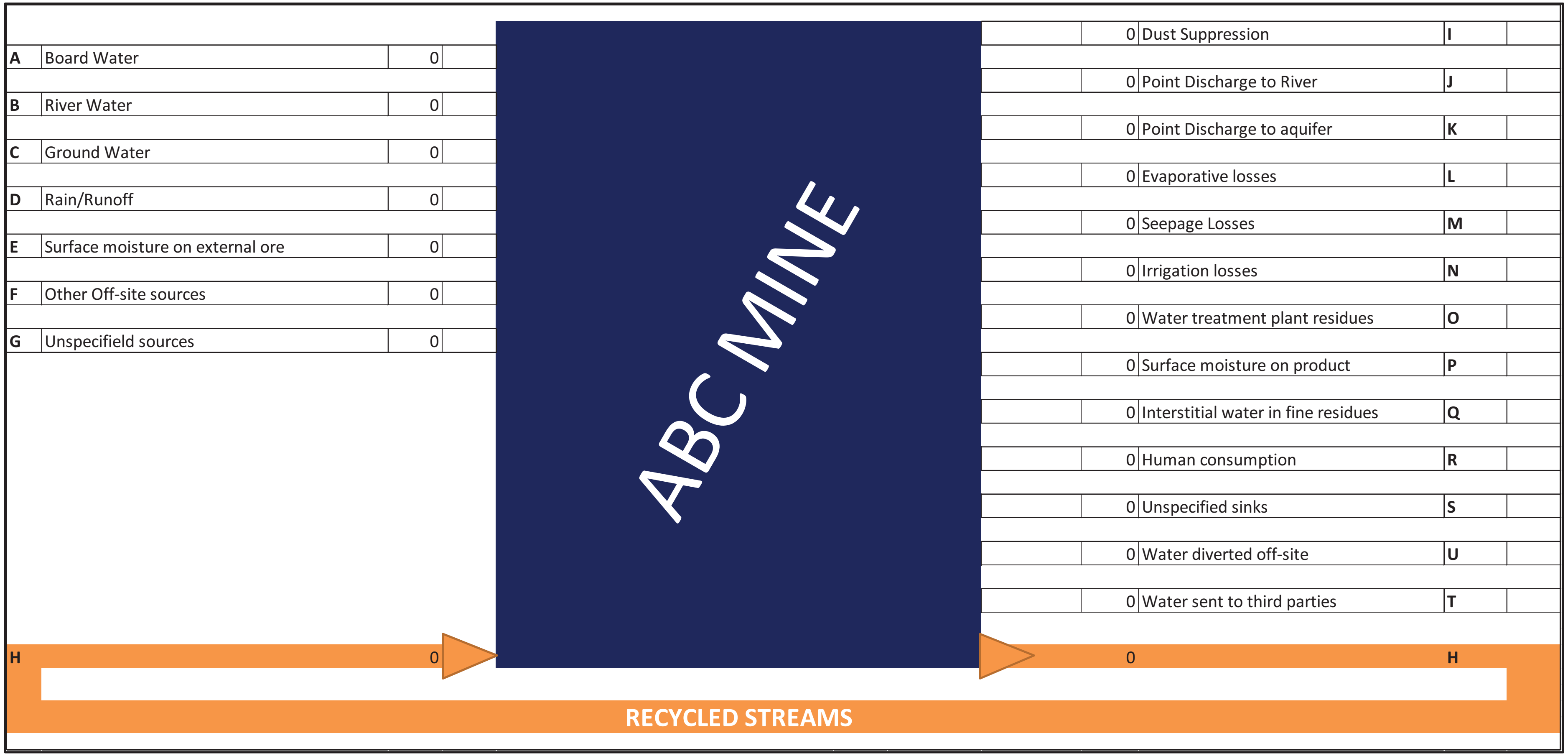

Figure 8: Consolidated WC/WDM evaluation for a mine

4.2.2 Definitions

The following definitions, as taken from Golder, 2016b, clarify some aspects of the WC/WDM terms used in the calculation of WUE indicators.

New water inputs,

"New water inputs" includes "Other off-site sources" and the following falls under this:

- Include water from a water distribution pipeline sent to the mine
- Treated sewage water from municipality
- Treated or untreated mine water from an adjacent independent mine
- Industrial wastewater obtained from a nearby industry

Although, technically, using the above sources in lieu of the traditional "Board / Potable Water", "Water abstracted from rivers", "Ground / Fissure water", direct rainfall and runoff, does not improve the water use efficiency of a mine, it does relief some pressure from the catchment in terms of water supply requirements. It should be noted that in order to conduct an assessment of whether it is beneficial to the catchment to use this water in lieu of the other water sources as discussed, the WC/WDM principles of the mine/industry/facility that is supplying the water must be considered.

Recycled inputs

4.2.2.1 Consumptive vs Non-consumptive water uses

It is critical to distinguish between consumptive and non-consumptive water uses when assessing WUE indicators. Consumptive water uses refers to all water uses that can theoretically be re-used or reduced through implementation of WC/WDM measures.

The non-consumptive water uses are grouped separately as these water uses are excluded when calculating consumptive water use and consumptive specific water use indicators.

Consumptive water uses

The following are consumptive water uses:

- Dust suppression
- Point discharge to river
- Point discharge to aquifers
- Ventilation air losses
- Evaporation from surface dams
- Seepage from surface dams
- Evaporation from mine workings
- Spills from surface dams
- Spills from mine workings

Non-consumptive water uses

Non-consumptive water uses include:

- Water diverted off-site to third parties
  - this is water sent to third parties directly without being affected or entering the mine operations
  - it includes water abstracted from boreholes/wells drilled around the opencast pit of an underground mine to draw down the aquifer which is then pumped to surface in its natural state
  - for beneficiation operations this includes all water sources which are abstracted to enable minerals beneficiation operations to proceed but are extracted at a point where they have not been affected by the operations, e.g. water abstracted from boreholes drilled at various points in the property which is then pumped to the surface in its natural state for use in the mineral beneficiation plant
  - it can be routed to an off-site third party such as a farmer, community, municipality or Water Board without even being used in the mine's operation
- Water sent off site to third parties
  - this is water that has been used or affected by the mine operations before being sent to third parties
  - it includes fissure water that is sent offsite even if this water is rapidly intercepted and pumped out of the mine

Recycled outputs

- Water in slurry from settlers

- this includes water from underground or surface mining settlers or silt traps and any water in thickened slurry cake where underground filter presses are in use and the dewatered slurry is hauled out of the mine together with the ROM ore

- Water in remined residues

- water use in mining operations aimed at recovering old mine residues that can still have value extracted with new minerals beneficiation technology – whether the residue material is physically mined and hauled to the plant or whether it is hydro-mined, re-pulped and pumped to the plant
- although some residues may contain water in addition to that used for mining, this is not explicitly considered as a water input.

4.3 RESULTS

4.3.1 Coal

Refer to Table 5 for the WUE indicators of some coal mines in South Africa. Figure 9 presents the consumptive water use for various coal mines in South Africa. As shown, the volume of water consumed varies across mines with a consumption of between 6-56 Ml/d.

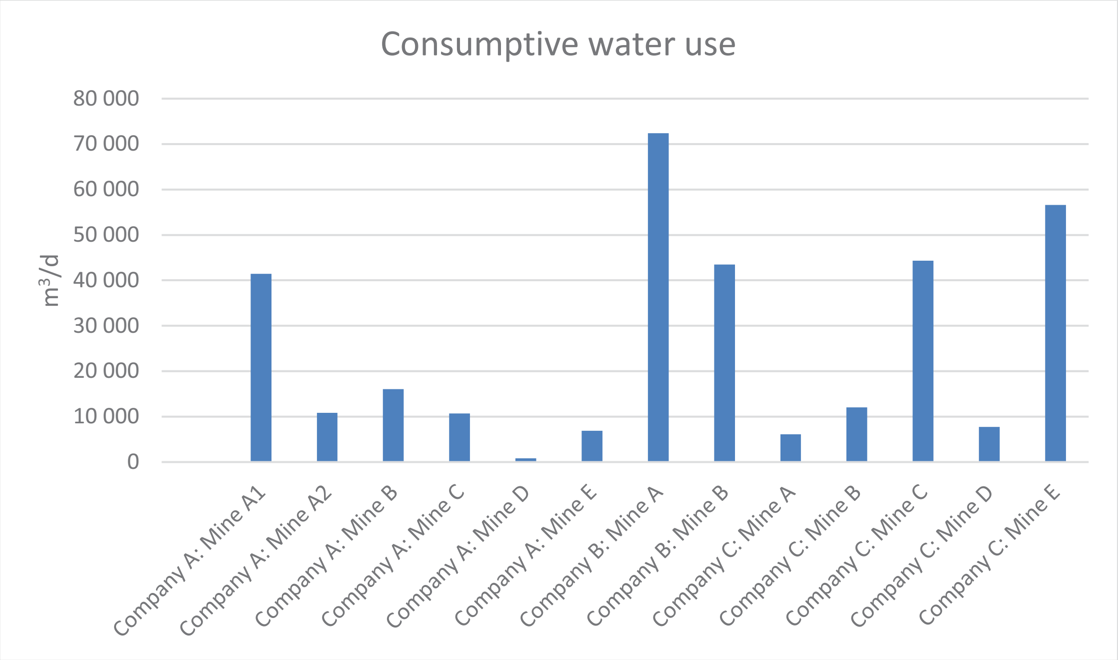

Figure 9: Consumptive water use for some coal mines in South Africa

Figure 10 shows the wastewater lost from these mines.

Figure 10: Wastewater lost for some coal mines in South Africa

Figure 11 compares the total specific and consumptive specific water use in cubic per ton of ROM of the various coal mines. As shown, these values differ quite considerable across the mines. The benchmark established for these indicators are 0.7 and 0.38 respectively, however many of the mines exceed these benchmarks. There is also no consistency with regards to water use across mines of the same company.

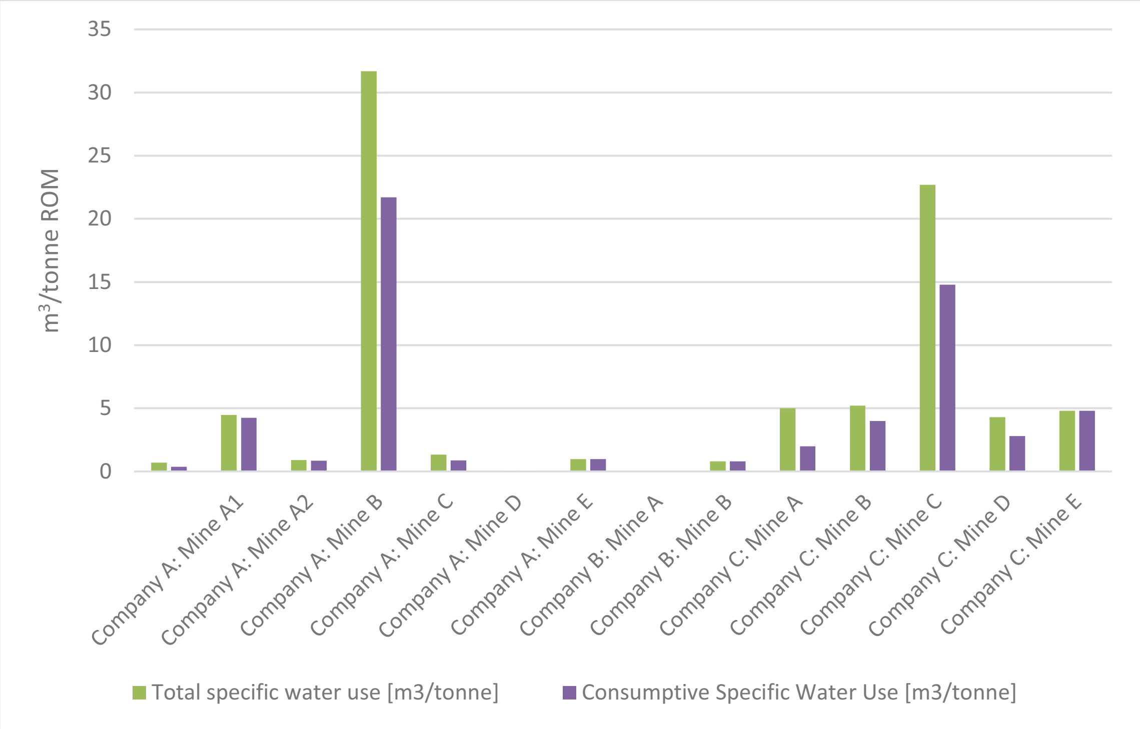

Figure 11: Total specific and consumptive specific water use for some coal mines in South Africa

Figure 12 and Figure 13 presents the total wastewater that is not re-used and the recycle ratio for these same mines with large variation across the mines.

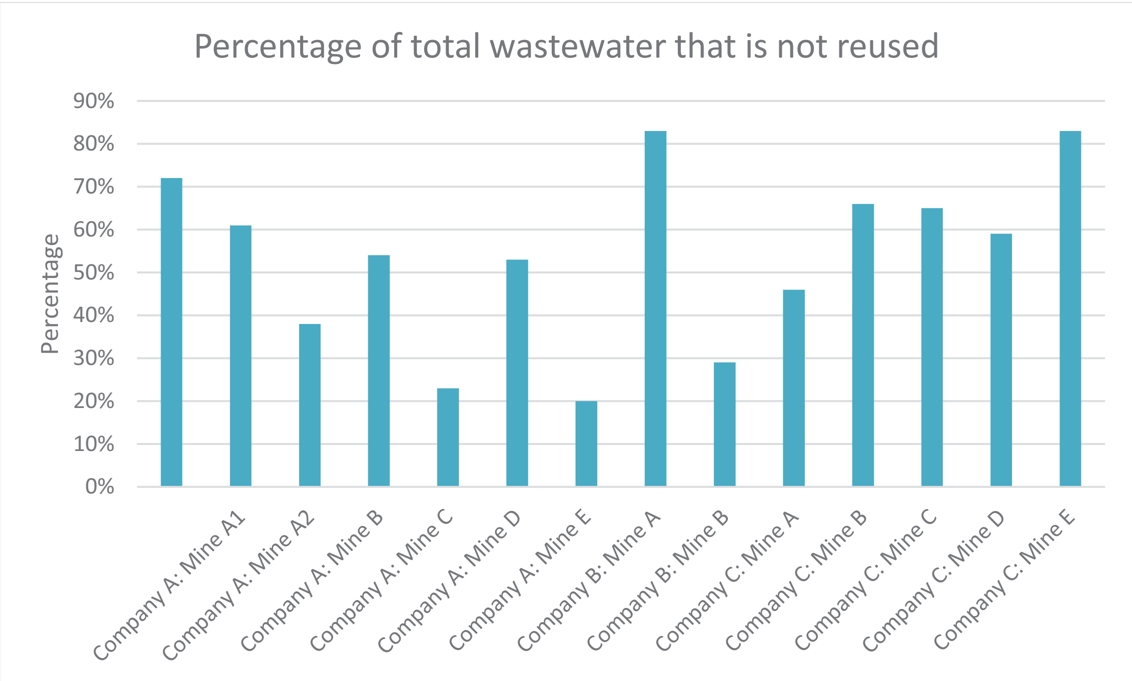

Figure 12: Percentage of total wastewater not reused for some coal mines in South Africa

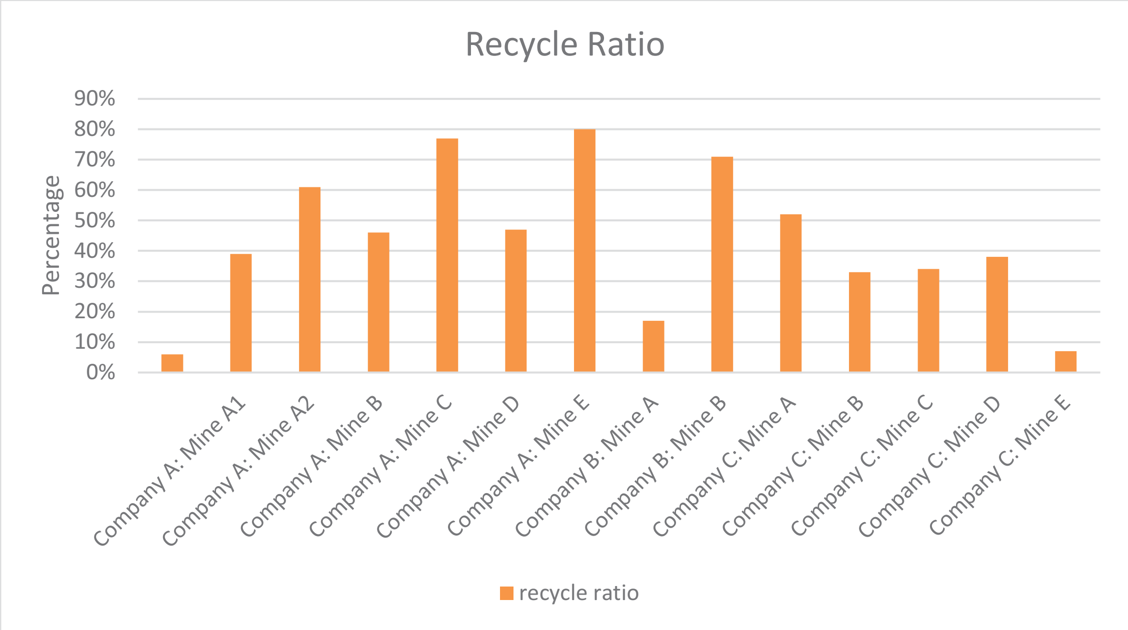

Figure 13: Recycle ratio (percentage) for some coal mines in South Africa

4.3.2 Gold

Figure 14, Figure 15 and Figure 16 presents a graphical representation of the WUE indicators that have been calculated for some Gold Mines. As with the coal mines a large amount of variation across the mines is observed.

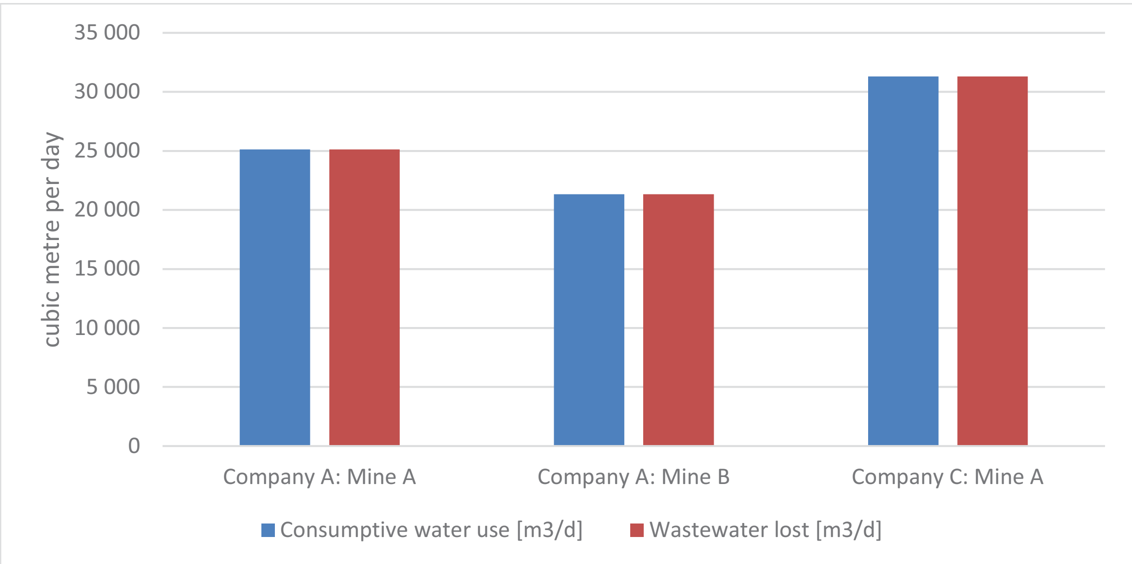

Figure 14: Consumptive water use and wastewater lost for some Gold mines

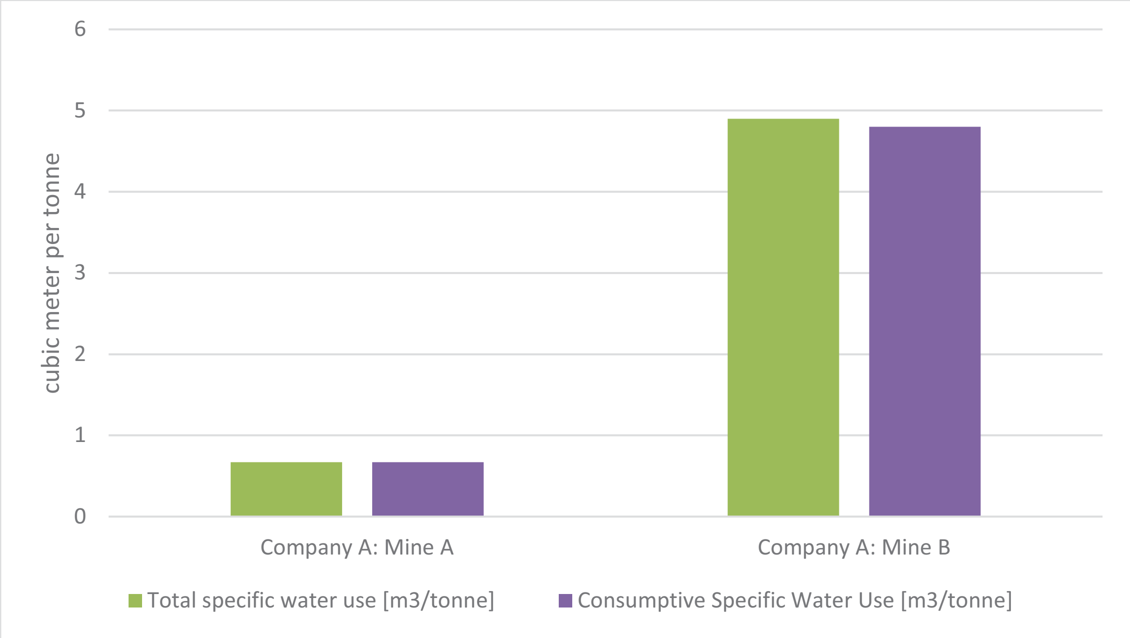

Figure 15: Total specific and consumptive specific water use for some Gold mines

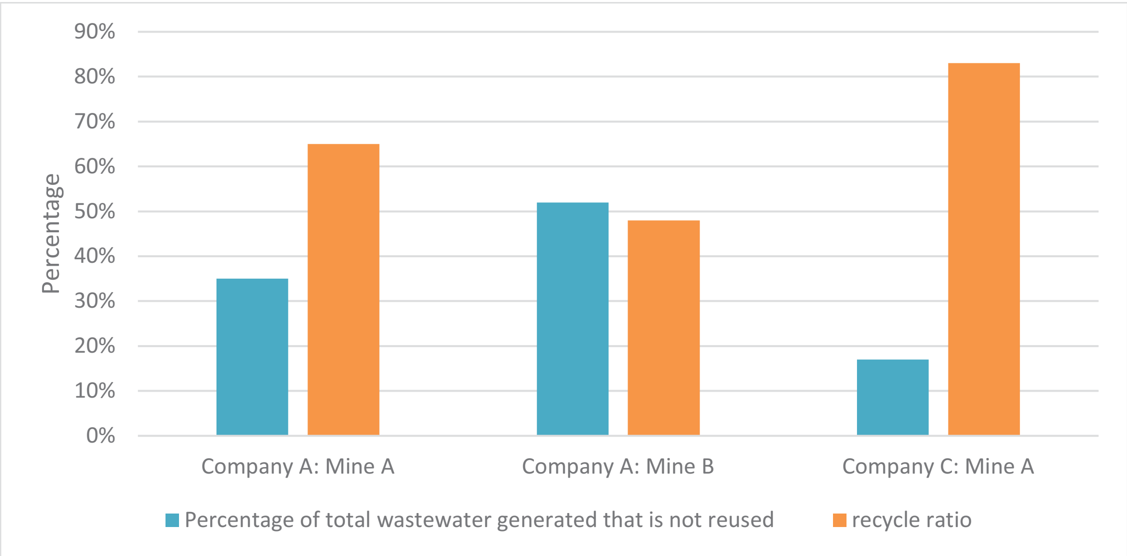

Figure 16: Percentage wastewater not re-used and recycle ratio for some Gold mines

4.3.3 Platinum

The same observation is made with Platinum mines as with Gold and Coal mines as show in Figure 17, Figure 18 and Figure 19.

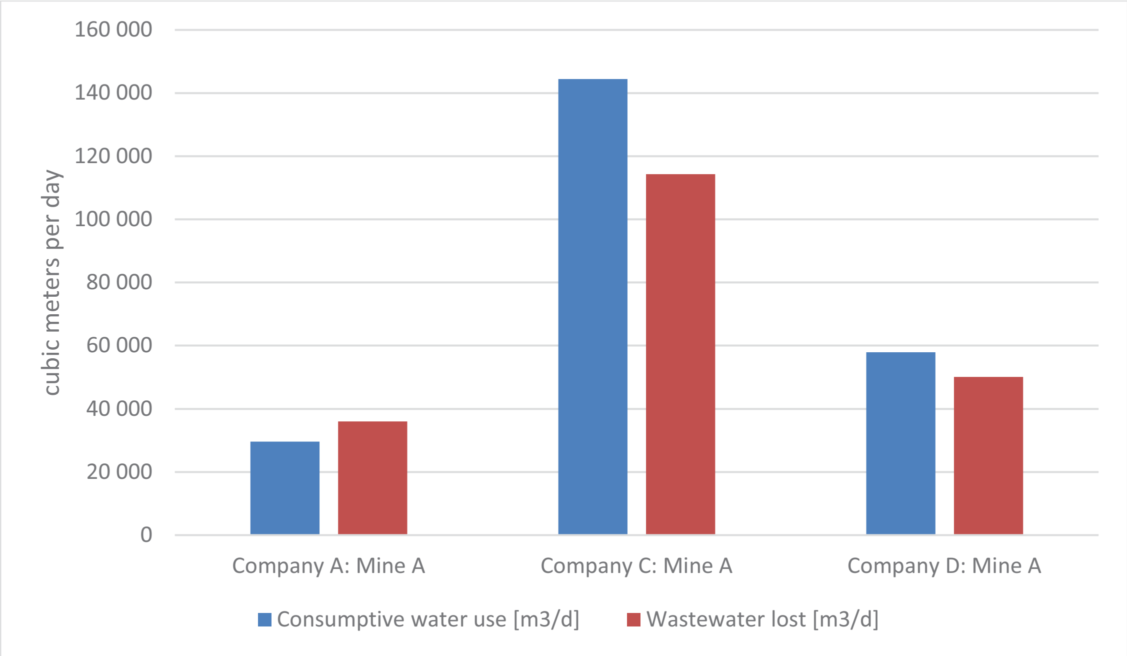

Figure 17: Consumptive water use and wastewater lost for some Platinum mines

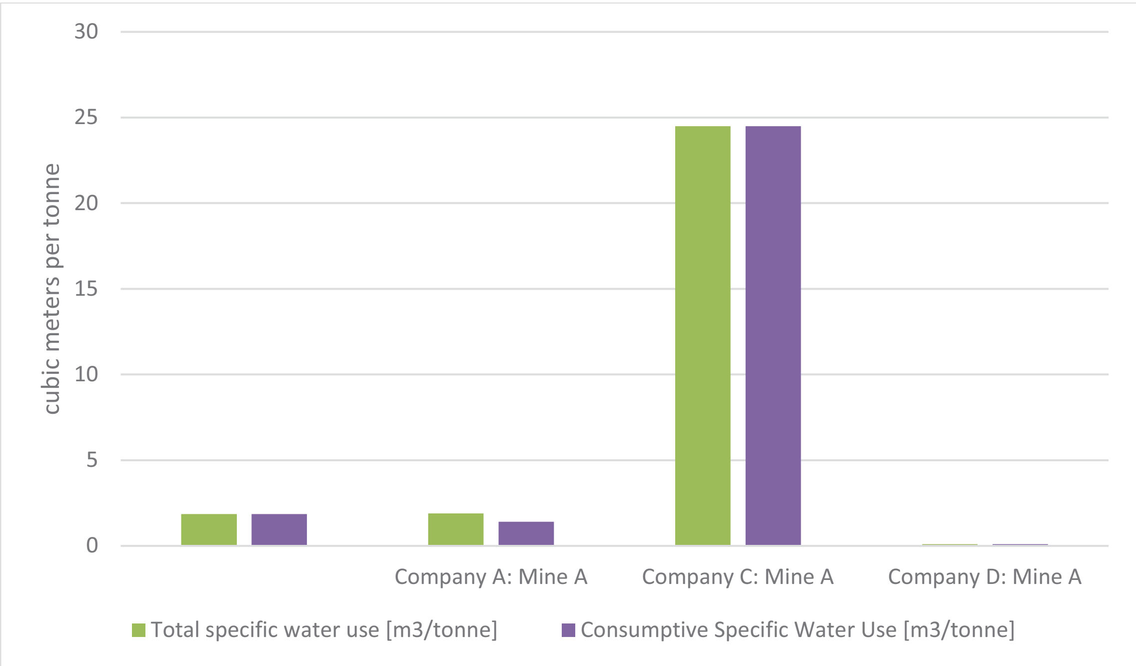

Figure 18: Total specific and consumptive specific water use for some Platinum mines

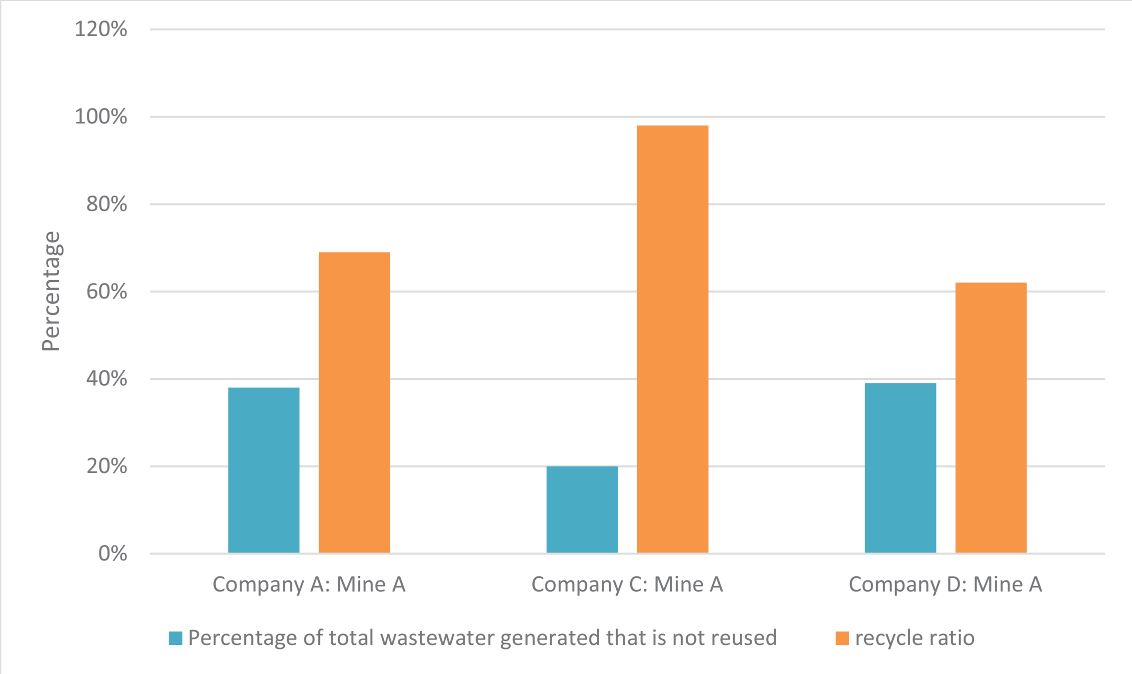

Figure 19: Percentage wastewater not re-used and recycle ratio for some Platinum mines

4.3.4 Diamond

Figure 20, Figure 21 and Figure 22 presents a graphical representation of the WUE indicators calculated for diamond mines. A similar variation across the mines is observed as with the other commodities.

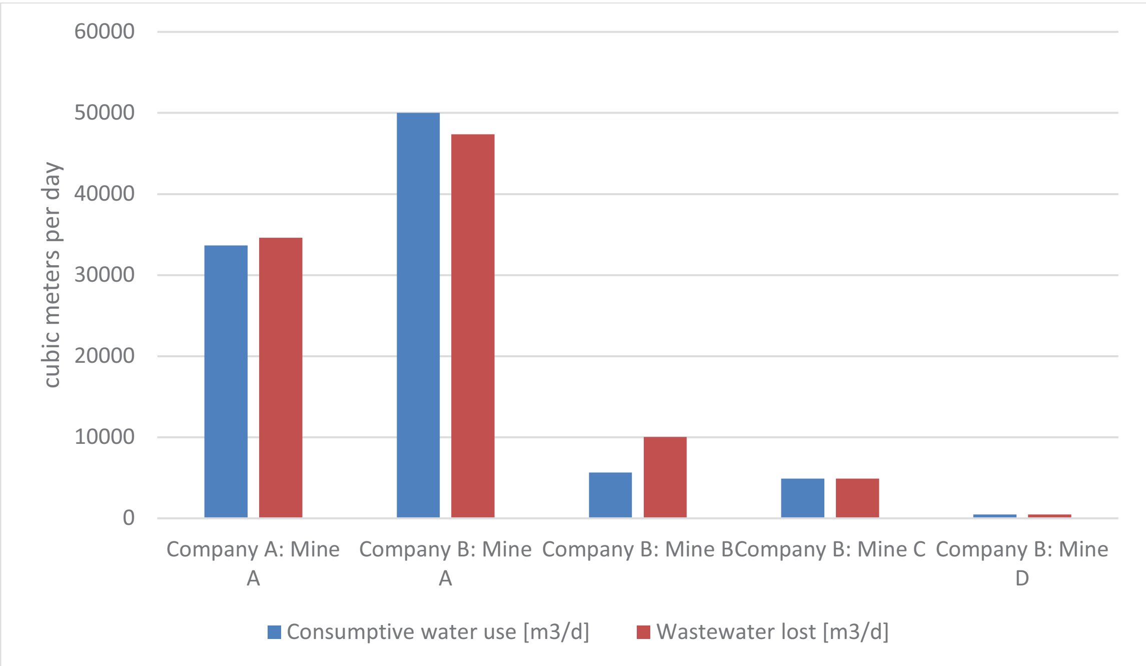

Figure 20: Consumptive water use and wastewater lost for some Diamond mines

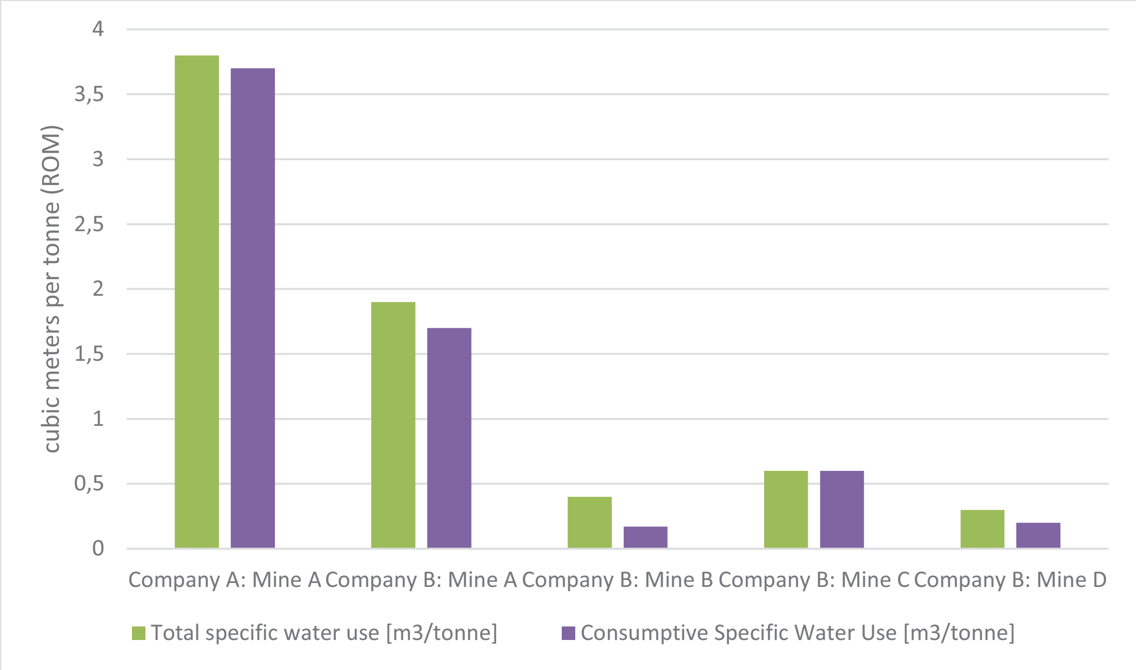

Figure 21: Total specific and consumptive specific water use for some Diamond mines

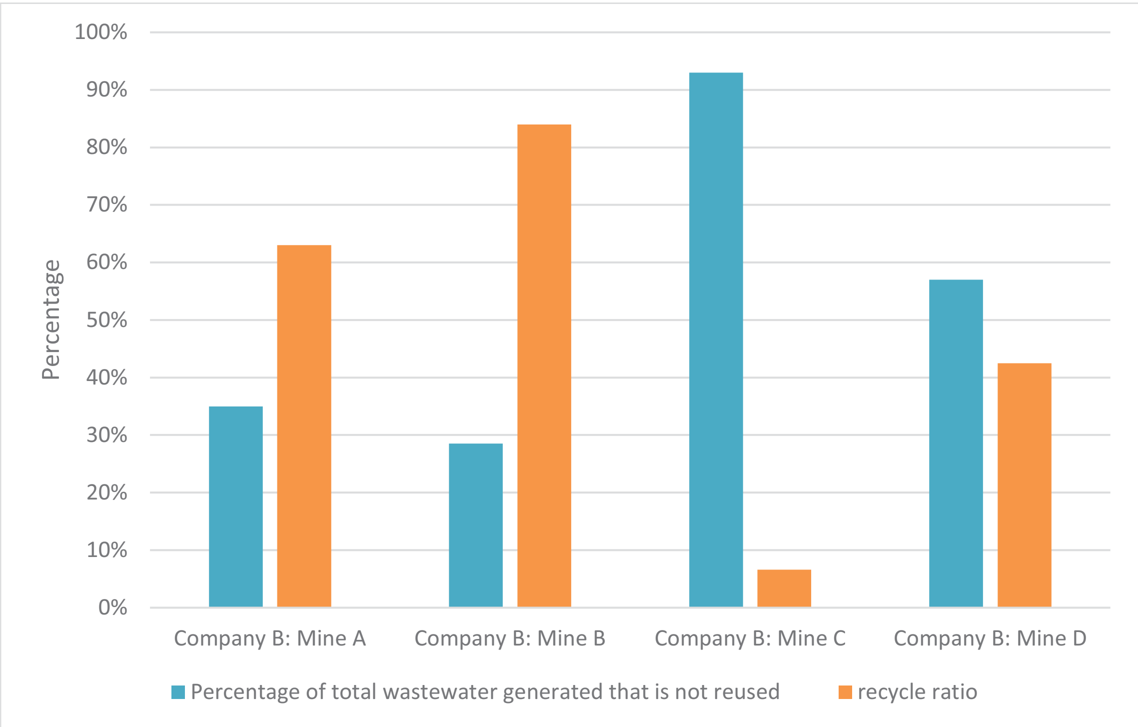

Figure 22: Percentage wastewater not re-used and recycle ratio for some Diamond mines

4.3.5 Other

Copper and chrome mines were assessed as part of the "other" commodity group. Figure 23, Figure 24 and Figure 25 presents a graphical representation of the WUE indicators calculated for these mines. A similar variation across the mines is observed as with the other commodities.

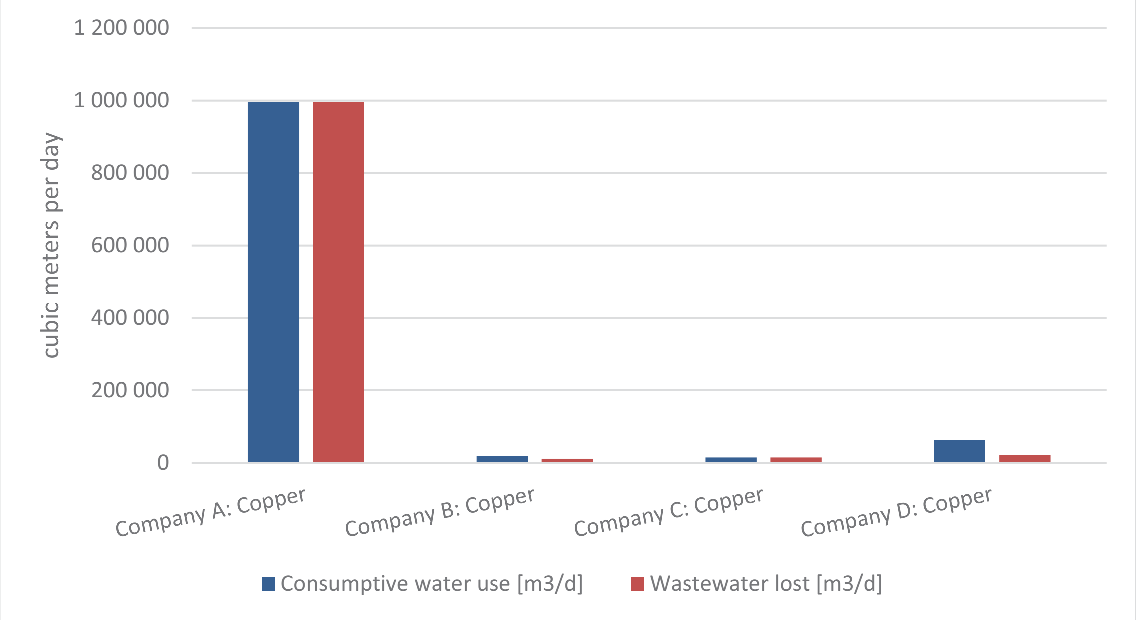

Figure 23: Consumptive water use and wastewater lost for some Copper and Chrome mines

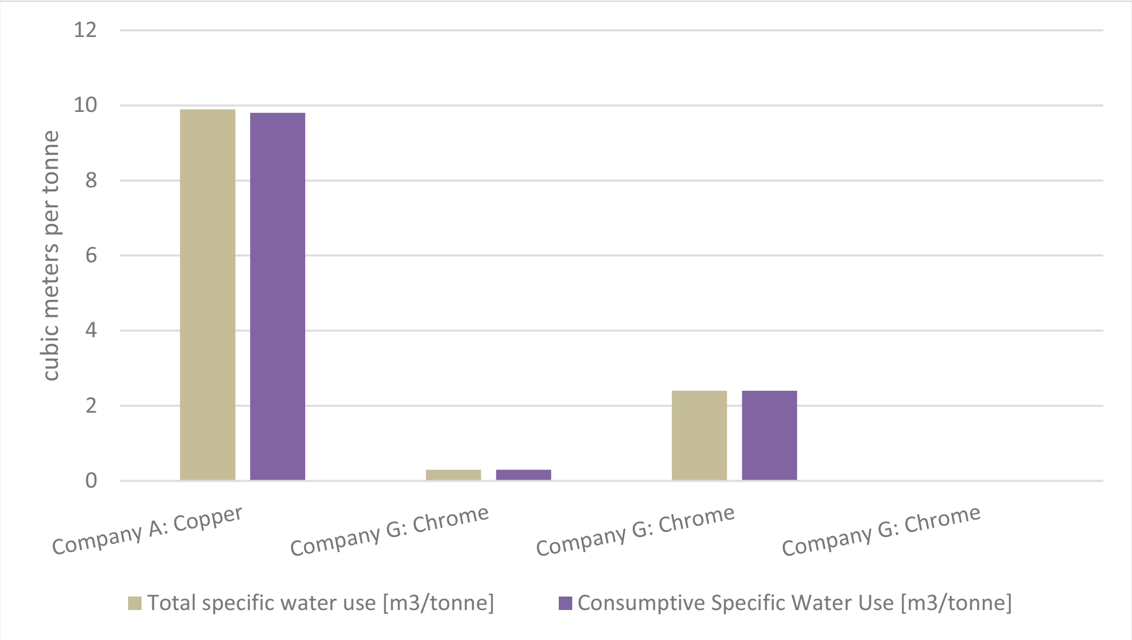

Figure 24: Total specific and consumptive specific water use for some Copper and Chrome mines

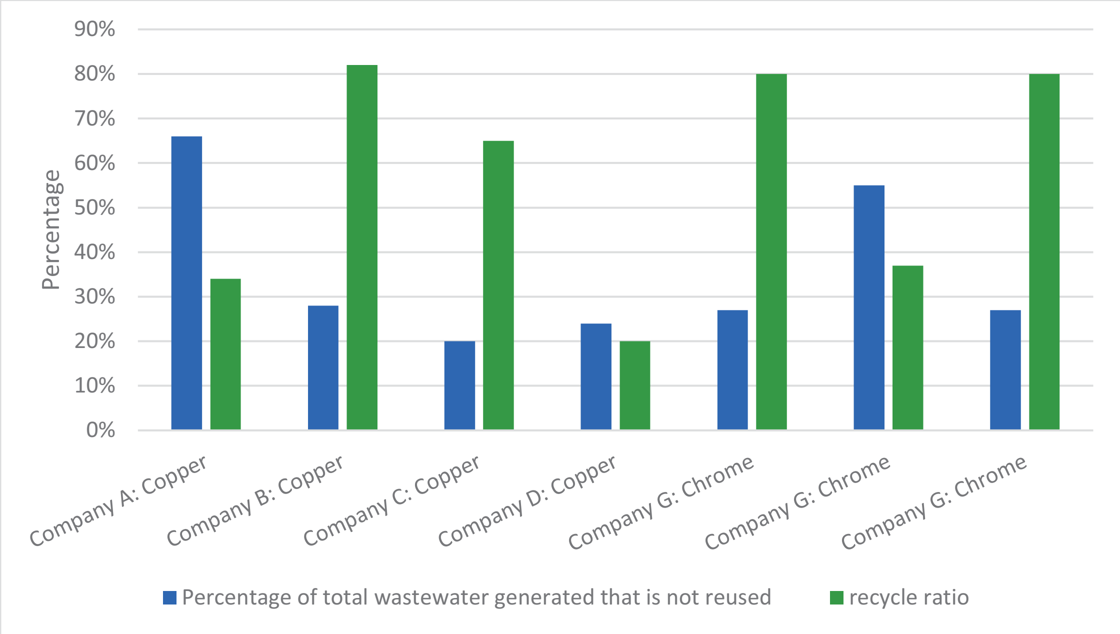

Figure 25: Percentage wastewater not re-used and recycle ratio for some Copper and Chrome mines

Table 5: WUE indicators for some coal mines within SA

No.	Company	Mine	Consumptive water use [m^3/d]	Wastewater lost [m^3/d]	Total specific water use [m^3/tonne]	Consumptive Specific Water Use [m^3/tonne]	Percentage of total wastewater that is not reused	recycle ratio
Benchmark					**0.70**	**0.38**	**72%**	**6%**
1	Company A	Mine A (a)	41 430	41 136	4.47	4.25	61%	39%
2	Company A	Mine A (b)	10 833	10 331	0.90	0.855	38%	61%
3	Company A	Mine B	16 065	10 990	31.7	21.7	54%	46%
4	Company A	Mine C	10 720	10 720	1.33	0.89	23%	77%
5	Company A	Mine D[3]	821	821	0.073	0.076	53%	47%
6	Company A	Mine E[4]	6 877	6 745	0.99	0.99	20%	80%
7	Company B	Mine A[5]	72 396	72 396	n.a.	n.a.	.83%	17%
8	Company B	Mine B	43 500	43 500	0.8	0.8	29%	71%
9	Company C	Mine A	6 085	6 518	5.0	2	46%	52%
10	Company C	Mine B[6]	12 062	11 927	5.2	4	66%	33%
11	Company C	Mine C	44 349	43 618	22.7	14.8	65%	34%
12	Company C	Mine D	7 746	7 481	4.3	2.8	59%	38%
13	Company C	Mine E[7]	56 579	50 796	4.8	4.8	83%	7%

All mines in Table 5 are South African mines

[3] *Mining operation commenced late in 2018*
[4] *Final year of mining*
[5] *Mine in rehabilitation stage*
[6] *Mine partially rehabilitated*
[7] Mine E represents and consolidation of Mines A to D

Table 6: WUE indicators for some gold mines within SA

Mine	Country / Province	Company / Mine	Consumptive water use [m^3/d]	Wastewater lost [m^3/d]	Total specific water use [$m^3/tonne$]	Consumptive Specific Water Use [$m^3/tonne$]	Percentage of total wastewater generated that is not reused	recycle ratio
Benchmark								
1	Ghana/Accra	Company A / Mine A	25 124	25 124	0.67	0.67	35%	65%
2	South Africa	Company A / Mine B	21 331	21 331	4.9	4.8	52%	48%
3	South Africa	Company B / Mine A	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]
4	South Africa	Company B / Mine B	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]
5	South Africa	Company B / Mine C	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]
6	South Africa	Company C / Mine A	31 297	31 297	TBC[8]	TBC[8]	17%	83%

[8] At the time of writing this report, insufficient information was available from the mine for the calculation of these metrics

Table 7: WUE indicators for some platinum mines within SA

Mine	Company	Mine	Consumptive water use [m^3/d]	Wastewater lost [m^3/d]	Total specific water use [m^3/tonne]	Consumptive Specific Water Use [m^3/tonne]	Percentage of total wastewater generated that is not reused	recycle ratio
Benchmark					**1.85**	**1.82**	**65%**	**39%**
1	Company A	Mine A	29 585	35 963	1.9	1.4	38%	69%
2	Company B	Mine A	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]
3	Company B	Mine B	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]
4	Company C	Mine A	144 455	114 361	24.5	24.5	20%	98%
5	Company C	Mine B	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]
6	Company C	Mine C	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]
1	Company D	Mine A	57 952	50 116	0.1	0.1	39%	62%

All mines in Table 7 are South African mines

Table 8: WUE indicators for some diamond mines within SA

Mine	Country / Province	Company	Consumptive water use [m^3/d]	Wastewater lost [m^3/d]	Total specific water use [m^3/tonne]	Consumptive Specific Water Use [m^3/tonne]	Percentage of total wastewater generated that is not reused	recycle ratio
Benchmark								
1	South Africa	Company A	33 666	34 604	3.8	3.7	28%	72%
2	South Africa	Company A						
3	South Africa	Company A						
4	Botswana	Company B	50 012	47 354%	1.9	1.7	35	63%
5	Botswana	Company B	5 662	10 029	0.4	0.17	28.5%	84%
6	Botswana	Company B	4 899	4 899	0.6	0.6	93%	6.6%
7	Botswana	Company B	480	480	0.3	0.2	57%	42.5%

Table 9: WUE indictors for some other mines within SA

Mine	Country / Province	Company	Commodity	Consumptive water use [m^3/d]	Wastewater lost [m^3/d]	Total specific water use [m^3/tonne]	Consumptive Specific Water Use [m^3/tonne]	Percentage of total wastewater generated that is not reused	recycle ratio
Benchmark						**0.96**	**0.65**	**52%**	**45%**
1	Zambia	Company A	Copper	995 929	995 929	9.9	9.8	66%	34%
2	Zambia	Company A	Nickel	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]
3	Zambia	Company B	Copper	18 764	10 851	TBC[8]	TBC[8]	28%	82%
4	Mozambique	Company C	Copper	14 520	14 980	TBC[8]	TBC[8]	20%	65%
5	DRC	Company D	Copper	62 263	20 964	TBC[8]	TBC[8]	24%	20%
7	South Africa	Company E	Nickel	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]
8	South Africa	Company F	Copper	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]
9	South Africa	Company G	Chrome	TBC[8]	TBC[8]	0.3	0.3	27%	80%
10	South Africa	Company G	Chrome	TBC[8]	TBC[8]	2.4	2.4	55%	37%
11	South Africa	Company G	Chrome	TBC[8]	TBC[8]	0.01	0.01	27%	80%
12	South Africa	Company H	Manganese	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]
13	South Africa	Company I	Manganese	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]
14	South Africa	Company J	Manganese	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]
15	South Africa	Company K	Manganese	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]	TBC[8]

CHAPTER 5: TECHNOLOGY AND PROCESS INNOVATION CASE STUDIES

5.1 DRY MINERAL PROCESSING

Introduction

Genet Mineral Processing (GMP) owns and operates FGX-1 Compound Air Separation Plants that successfully de-stone ROM coal and upgrading ash and calorific value to an acceptable domestic power utility specification. GMP is the sole agent in Southern Africa for the FGX Dry Compound Mineral Separator. This is a purpose-designed, dry mineral processing plant offering mining companies a clean, efficient and environmentally friendly solution to mineral processing needs, with significantly reduced operating costs compared to traditional Dense Medium Separation (DMS) plants which utilises large volumes of water. The technology provides a cost-effective option for upgrading low grade coal by "de-stoning" this material over a vibrating screen in conjunction with air from a force fan. No process water is used in this process and subsequently no slurry ponds are required, thus reducing capital costs. The FGX plant integrates the separation principles of an autogenous medium separator and a conventional table concentrator. Three streams emanate from the FGX: product, middling and discard. A dual dust collection system further adds to the environmentally friendly nature of the plant. Dry mineral processing uses less electricity compared to a DMS plant while additional savings are realised though low maintenance costs.

Description of FGX Beneficiation Plant

The plant consists of primary beneficiation which involves crushing and separation the ROM from the pits. The crushed ROM is then conveyed to the FGX Plant where it is further processed. The FGX plant works on the principle of using high pressure air to separate coal from stone or other impurities. Air pressure that is created by using a high-pressure fan is forced through a vibrating separator deck. A layer of coal and stone is fed on the deck. The light particles (coal) becomes fluidized and moves upwards. The high-density material remains in contact with the table and moves downwards. This contrast in density allows the particles to separate and move towards the point of discharge. There are currently two types of air separation plants available, *viz*. FGX and FX. Figure 26 displays the internal process of the FGX plant.

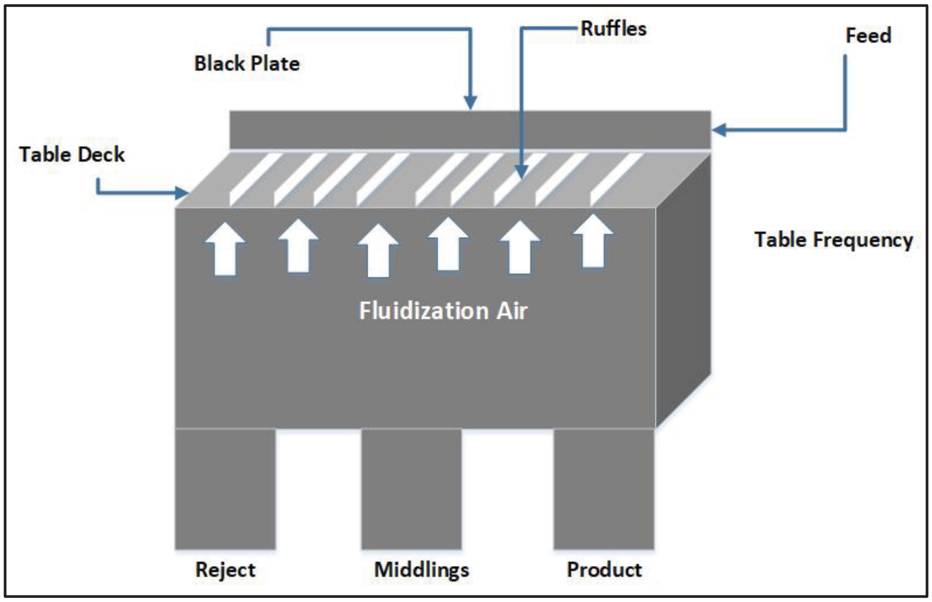

Figure 26: Simplified process diagram of the FGX plant

The FGX/FX plant can be designed to produce reject, middling and product. This plant specifically has been designed to produce only discard and product material. Figure 26 is a process flow diagram of the plant process at Mine X.

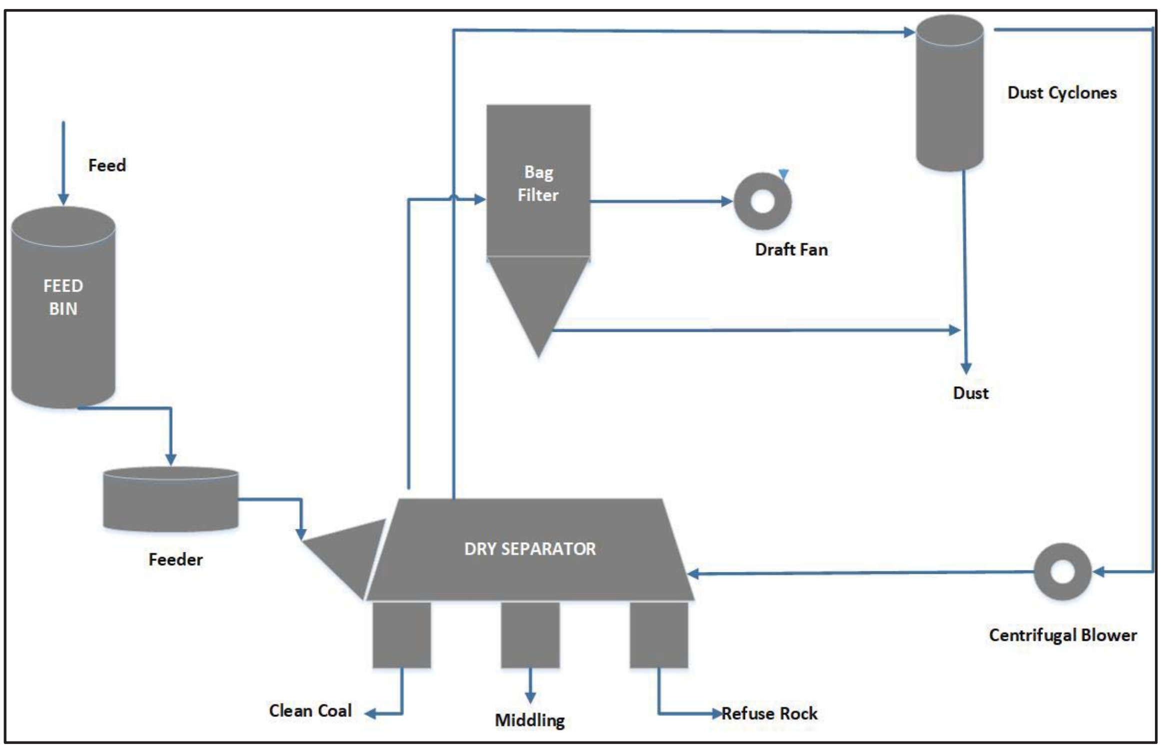

Figure 27: Typical FGX plant layout

Application of the FGX technology

The technology can be used in low grade coal operations. Table 10 highlights the advantages of FGX over traditional DMS. The FGX technology becomes a viable technology selection if the intended mine requires a beneficiation plant urgently. It is a logical choice especially the necessary environmental clearance is much less complicated than for wet processing plants. There is also limited infrastructure required and the FGX plant can be run by a generator. The plant is inexpensive and is compatible enough to be relocated.

When considering the application of the FGX technology the following needs to be considered (de Korte, 2010);

- The availability of water for processing
- The location of the mine and the customer
- The specific nature and the washability characteristics of the raw coal
- The specifications and the price of the product coal
- The degree of control of the product quality and the implications of delivering out of specification coal
- The availability of electricity and other infrastructure
- The cost and availability of labour within the area
- The duration of the project

Table 10: FGX VS DMS

Description	**Air plant**	**DMS plant**
Process water	None required	Requires water
Thickeners and flocculant dosing	None required	Requires Thickeners and flocculant dosing
slurry ponds	None required	Requires slurry disposal
Dewatering of fine product	None required	Requires dewatering of fine products
Maintenance of slurry pumps, CM pumps, etc.	None required	Requires maintenance
Installed powers	Less than DMS plant of similar capacity	Higher than Air plant of similar capacity
Capital expenditure	Less than DMS plant of similar capacity	Higher than Air plant of similar capacity
Rehabilitation Liability	Limited no slurry ponds	Rehabilitation of slurry disposal system

Description	Air plant	DMS plant
Operational cost	Less than DMS plant of similar capacity	Higher than Air plant of similar capacity
Beneficiation of near dense material	Application limited	Suitable for beneficiation of near dense material
Feed material fines moisture greater than 10%	Prefer to screen out fines with moisture greater than 10%	Suitable for beneficiation of wet fines

Figure 28 represents the ash percentage of the ROM, product and fines for a general FGX plant. The plant can operate at ROM ash percentages of 33.08%. It also reduces the ash content by 3.45%.

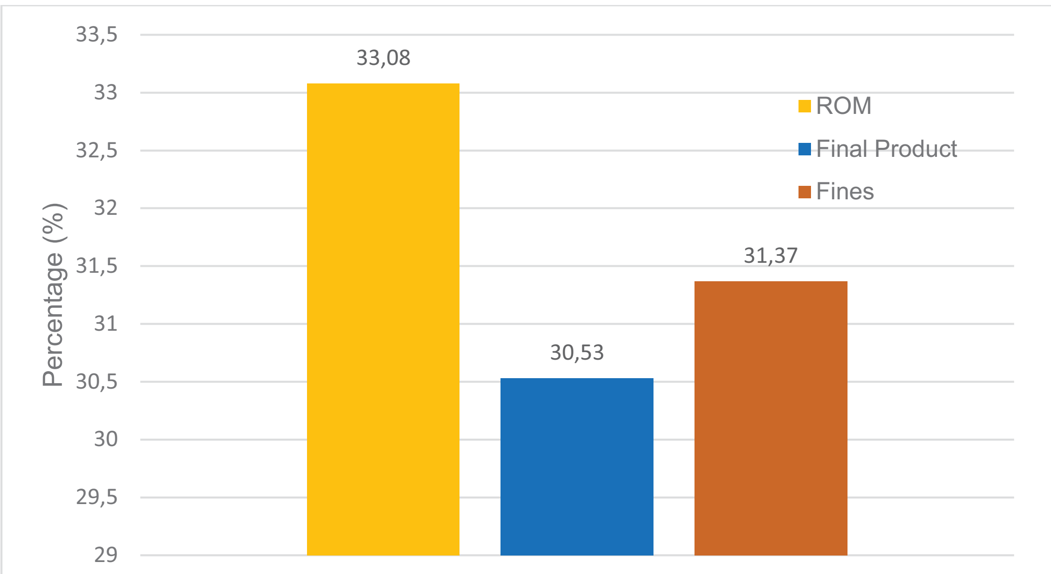

Figure 28: Ash percentage of ROM, Product and Fines for general FGX plant

Other applications within South Africa

Mine:	Capacity;	Plant Tons over Life of Mine;	Status:
Bethal District	1000 tph	12 000 000 T	Resources depleted (Mine closed)
Carolina District	250 tph	1 500 000 T	Resources depleted (Mine closed)
Ogies District	250 tph	1 200 000 T	Operational
Kriel District	250 tph	1N 346 Kt	Operational

The FGX/FX plants are compatible plants that are assembled in China and imported to South Africa. The mechanical plants required for the FGX plant are locally available and sourced by Genet. Genet is also involved in the installation and maintenance of these plants. They have recently procured the FX plant which is an upgrade and newer version of the FGX plant. Table 11 displays the technical parameters for the FX plant. The plant type is dependent on the treatment capacity and the feed type of coal to the FX plant.

New Arising technology

Table 11 represents the technical parameters of the new FX technology that will be implemented by Genet. This technology has been commissioned in China and has a much more improved efficiency than the FGX plants.

Table 11: Technical parameters of FX type

Technical indexes	Treating capacity	Feed range	Feed moisture	Footprint	Power for FX unit
Unit	**t/h**	**mm**	**%**	**m×m**	**KW**
FX-12	100-120	0-120	＜11	10×20	360
FX-20	180-200	0-120	＜11	19.5×22	650
FX-25	220-250	0-120	＜11	20×22	700
FX-24A	200-240	0-120	＜11	20×20	720
FX-40A	360-400	0-120	＜11	39×22	1300
FX-48A	400-480	0-120	＜11	40×20	1440
FX-50A	440-500	0-120	＜11	40×22	1400

Challenges faced

The following section discusses some of the operational problems faced by the FGX.

- Using lock nuts to prevent the autorotation of the vibration bed. The adjusting bolts that were used did not keep the vibrating table at the optimal angle which resulted in a reduced efficiency of the FGX.
- The perforations within the table deck became clogged with fine wet coal which resulted in the need to stop production. The fine coal (<6 mm) contains the most moisture.
- High density sand-sized particles settle within the air blower and constrict the air flow to the table deck. This could only be prevented by periodic cleaning and maintenance of the blower pipes.
- Due to the amount of dry coal dust particles that are produced, excessive dust particles that are present within the feed coal stream are carried by the air dust and cyclone overflow air, which is recycles through the table deck. A portion of this air is continuously drawn off by a separate fan which is routed to a bag filter for the removal of the dust before venting to the atmosphere.

5.1.1 Case studies associated with FGX technology

CASE STUDY 1 – KLIPFONTEIN MINE – Minimising potable water consumption by using FGX

Introduction

This case study documents the WC/WDM measures implemented by the Klipfontein Mine operation. The mines are located within the Waterberg catchment in Delmas, Gauteng, South Africa. The Klipfontein mine is an opencast coal mine that is currently processing low grade coal using the FGX dry air technology. The coal product from this plant is supplied to the Kusile Power plant, which is a coal fired power station located nearby. This initiative does not require a source of water for its process and its capital investment cost is far less as compared to traditional Dense Medium Separation. The mine has optimized its use of water and does not require any external sources of water. It has also improved the quality of the ROM for the power generation market. Previously, the mine did not have a dedicated water source that could sustain its water requirements for conventional DMS processing. The operational costs were becoming too extravagant for the mine. The FGX plant was installed in the beginning of 2017. From its commencement it has reduced the strain on water sources required by the mine and has also improved the quality of raw coal for the power generation market.

Description of Process:

The Mine is an open-pit operation that uses drilling, blasting as a mining method. The material handling (both coal and overburden) are done by means of a truck and shovel.

The mine does not require water from any external sources. Naturally occurring water from fissures that are liberated during the mining process is collected and pumped to a water holdings dam. The dirty water that is a result of runoff water that has become contaminated through contact with carbonaceous material is collected in the mines pollution control dam. These dams are not covered and experience rainfall and evaporation. Water from the pollution control dam is used for dust suppression of the haul roads and various conveyor transport points at the plant.

Figure 29 displays the calorific values (CV) of the ROM, Final products and Fines weighted average for Klipfontein mine. From the graph the typical ROM has a CV of 15.41 MJ/kg this is improved to 16.38 MJ/kg by being beneficiated in the FGX plant. Eskom requires a coal supply that has a CV <21 MJ/kg for their Kusile power station. The FGX plant has not only reduced the mines consumption of water it has also improved the CV of the product coal supply.

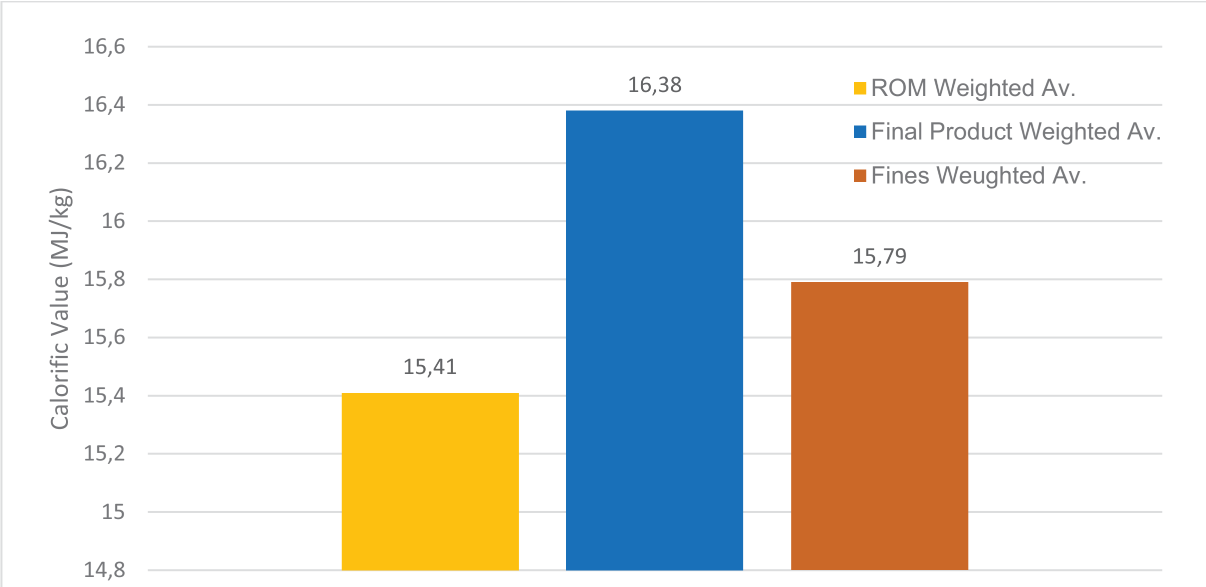

Figure 29: Calorific Value of ROM, Product and Discard from Klipfontein Mine

CASE STUDY 2 – EXXARO NORTHERN BLOCK COMPLEX – Minimising fresh water through extensive water recycling

Introduction

This case study documents the water conservation and demand management measures implemented by Exxaro. The objective of the initiative was to find a low-cost method to destone raw coal and discard for subsequent use in power generation. The FGX dry processing air table was selected for the study. The unit provides a simple and inexpensive approach to removing stone and shale from low-grade raw coal. The unit was supplied by the Tangshan Shenzhou Machinery Company and works on similar principles mentioned above. The pilot testing was executed at the Exxaro facilities with the technical assistance of Coal tech. A separate study performed by Exxaro and Coal tech focused on performing an economic analysis to compare the FGX with wet jigging and Dense Medium Separation.

A preliminary test program was carried out to test the coal from NBC. These results showed that the coal from NBC is quite difficult to upgrade to Eskom quality with the FGX unit. Samples of Seam No. Seam 3 and Seam No.4 were tested. The test revealed that the product ash content obtained on the No. 4 Seam is in agreement with typical Eskom specifications. The No Seam 3 product does not meet the Eskom specifications. Other samples from the same seams where tested to increase the reliability of the experiment.

Description of Process:

The FGX plant was moved to NBC and test runs began on the 9th of June 2009. The raw coal from the different seams were supplied by the mining department. The coal was crushed to a top size of 50 mm using a crusher rig. This was then fed into a feed bin prior to being fed into the FGX unit. During the operation of the unit samples of the product and discard from their respective chutes where sampled on site. Efficiency tests were conducted on site and in an external lab.

To avoid any operational problems a screen was used to screen out the fine coal particles (<6 mm).

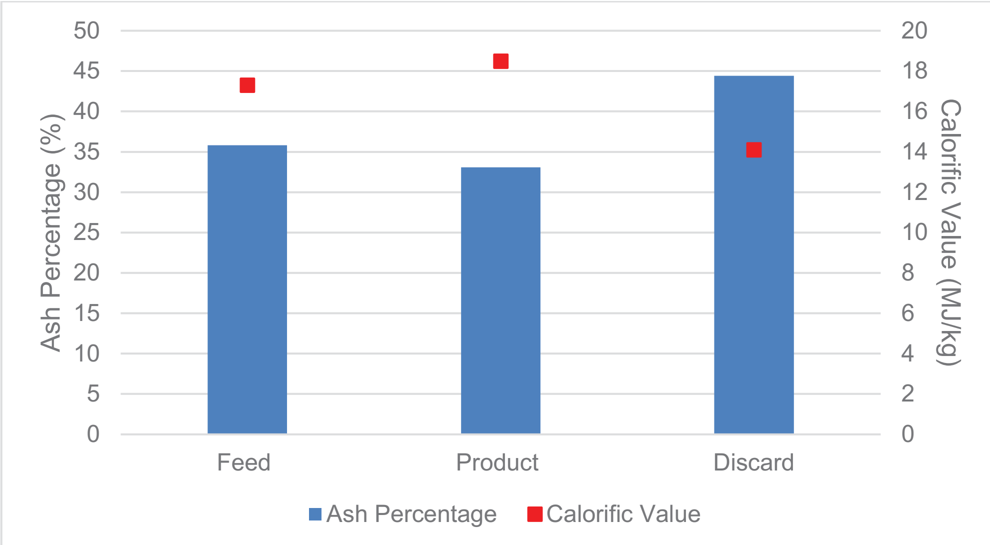

Figure 30: No. 3 Seam coal

Figure 30 displays results indicated that the CV of the coal has only improved by 17.3 MJ//kg to 18.5 MJ/kg. This is not as significant as compare to other beneficiation techniques. The sulphur content of the coal was reduced significantly from 1.2% to 0.6%.

Efficiency tests measure the high cut point density and yield. The efficiency test results done on the Screened No. 3 seam indicated that the separation was very high (>2.4) and could not be derived from the partition curve. The efficiency results proved that there was a small degree of quality improvement that was achieved (de Korte, 2010).

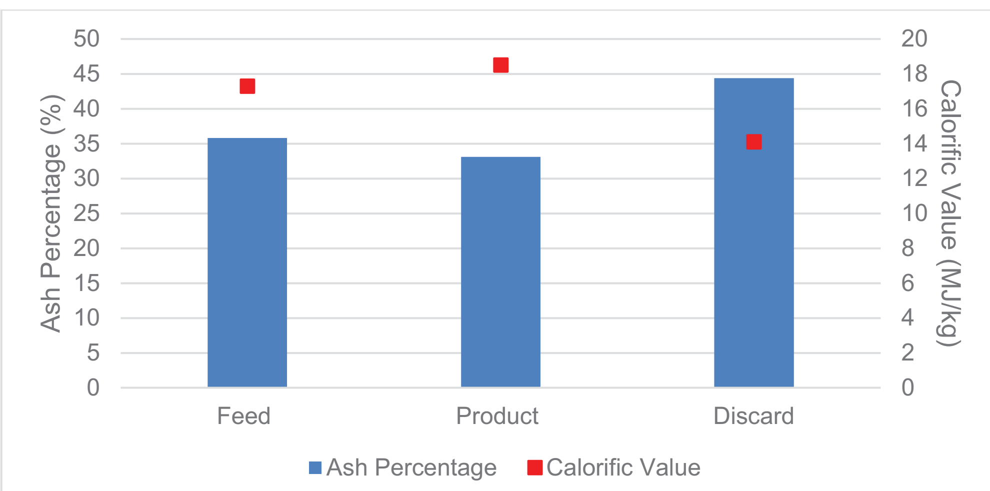

Figure 31: No. 4 Seam coal

It was indicated by Figure 31 that the No. 4 Seam coal was worse than the No. 3 Seam coal (this was determined by the feed ash coal which was 35.8 and 42.9% for the No.3 and No.4 Seam coal respectively). The efficiency test results showed similar results to that of the No. 3 seam coal. There was a small degree of improvement within the No.4 seam coal (de Korte, 2010).

CASE STUDY 3 – XANTHUM PALESA COLLIERY – Using FGX beneficiation

Introduction

Xantium Trading 342 (Pty) Ltd., a coal processing Specialist Company, installed a 1-tph FGX unit, similar to the Exxaro unit. Xantium has secured an agreement with the Chinese supplier and has become one of the South African suppliers that distribute, install and maintain these FGX units. Xantium has several operating FGX within the South African Mining industry. The unit is shown in operation at Palesa Colliery in Figure 32. The management of Xantium incorporated Coaltech into their extensive tests and research on the FGX units at their sites the following case studies reflects some of these results that were obtained (de Korte, 2010).

Figure 32: Xantium FGX unit at Palesa Colliery (de Korte, 2010)

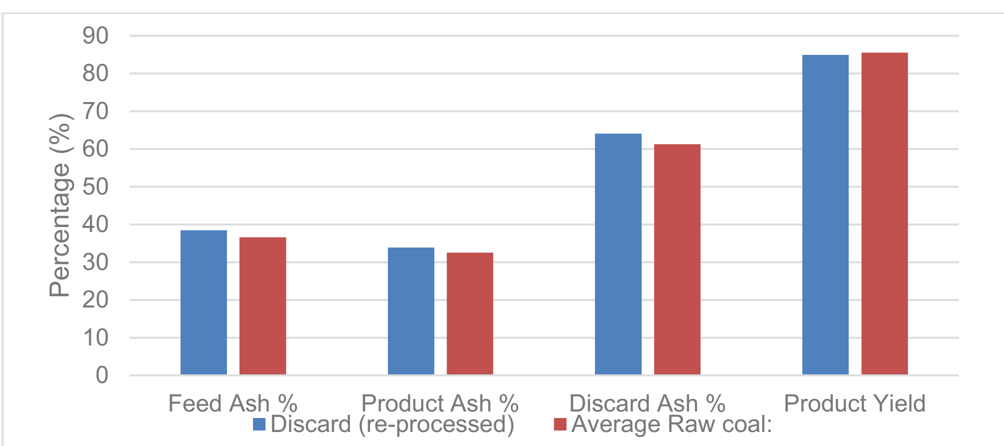

Figure 33: Results obtained from the Xantium FGX

The ROM from the mine is screened prior to being fed to the FGX plant. The plant also reprocesses some of the discard. The reprocessed coal shows a feed ash content of 38.5%, post beneficiation the product ash content is reduced by 4.6%. The product yield for the reprocessed discard is 84.9%. On average the ROM has an ash content of 36.58%. The ash content is reduced by 4.05% with a yield of 85.56% (de Korte, 2010).

CASE STUDY 4 – XANTIUM MIDDELKRAAL COLLIERY

Xantium has constructed a full-scale FGX plant at Middelkraal Mine near Bethal which consists of two FGX-24 units. The plant will be able to process approximately 480 tons per hour of raw coal. This plant is planned to start operation in March 2010. Coaltech has been invited to assist with the performance evaluation of the plant once it is in full production. A photograph of the plant at Middelkraal is shown in Figure 34.Results for this have not been made available (de Korte, 2010).

Figure 34: FGX 24 unit at Middelkraal (de Korte, 2010)

CASE STUDY 5 – INVESTIGATION OF THE FGX OPERATION AGAINST CONVENTIONAL BENEFICIATION PROCESSES – CASE STUDY DONE BY COALTECH

For this case study a hypothetical mine with the following assumptions was used

1) ROM production of 3.6 million/year
2) CV of 21 MJ/KG
3) Raw coal was crushed by 50 mm
4) Screening of coal to remove the minus 6 mm size fraction (fine coal) constituents

The following processing results were obtained.

Table 12: Processing results

	FGX	**JIG**	**Dense Medium**
Product Yield (%)	61.74	63.37	64.21
CV of product coal (MJ/kg)	19.83	21	21
Ash Content of product coal (%)	35.1	32.01	32.01
Total moisture content of product coal (%)	6.88	8.82	8.82
Capital cost (R/ton/hr)	40 000	80 000	200 000

The results from Table 12 indicated that the dense medium results had the highest product yields. The moisture content achieved by the FGX was the lowest. The FGX unit failed to produce the required product quality. The product specification that was achieved by the Jig and dense medium separator was at a much higher saleable quality as compared to the FGX.

The results also show that the FGX is the least profitable of the other options. Wet Jigging proved to be the most profitable. The study concluded that the FGX was the lowest in terms of capital and operating costs but produced the lowest yield and recovery efficiency.

CASE STUDY 6: DRY MINERAL PROCESSION

This case study involves a South Africa Coal Mine. Genet Mineral Processing has installed three Chinese-manufactured 120 t FGX sorters for dry coal beneficiation the mine in Witbank. Dry coal beneficiation is significantly cheaper than wet beneficiation and is suitable for use in areas such as the Waterberg, which hosts about 40% of South Africa’s remaining coal resources and has limited water supplies. The method costs about 70% less than wet beneficiation. The only drawback of dry beneficiation is that it cannot be used to beneficiate export-grade coal.
The process involves destoning and deshaling process but does not involve an upgrading process that raises the calorific value of coal to improve its burning. Dry beneficiation only removes the stone and shale from the coal, improving its use in power generation. Removing the waste rock at the mine site also reduces the transport costs.

Features of the FGX Separator include:

- Completely dry process
- Simple engineering
- Environmentally friendly and cost effective
- Easy to set up and operate
- Low maintenance

Typical applications include:

- Steam coal de-stoning
- De-stoning of metallurgical coal
- Dry processing of high-sulphur coal
- Coal prep in arid regions
- Processing of low-rank coal
- Destoning of coal in power utilities and cement plants

At the time of writing this report, data for the analysis of this case study was not available.

5.1.2 Conclusions or recommendations based on the case studies presented above

The FGX unit is an inexpensive technology that is used to beneficiate coal. Many applications have seen successful results and some case studies mentioned above have not shown promising results. The FGX should be used in specific cases where there is a shortage of water and where only destoning of coal is required.

5.2 FILTRATION

CASE STUDY 7 – THE APPLICATION OF FULL-FUNCTION HIGH PRESSURE FILTER PRESSES IN TAILS DEWATERING

Mineral processing plants have historically deposited ultra-fine tailings slurries in storage facilities where water has partially been recovered using overflow weirs or been lost via evaporation and seepage. This lost water places pressure on the environment through ground-water pollution and raw water make-up requirements. Additionally, modern environmental legislation and requirements have drastically increased the cost of constructing and maintaining these facilities.

Through the correct application of full-function, plate and frame filter presses, ENPROTEC has, over the past 10 years and more than 30 operational processing sites, successfully developed a highly effective and cost efficient, ultra-fine tailings dewatering solution which has debunked the historical perception that tailings filtration is expensive and uneconomical. This process improves materials handling and placement of fines, reduces raw water requirements and eliminates the need for slurry storage facilities at capital expenditure (CAPEX) and operational expenditure (OPEX) values that are comparable to that of traditional thickening and pumping solutions.

Introduction

Companies in the mineral processing business have proven that dewatering technologies, and more specifically in this instance, filter presses are a viable, cost effective means by which the dewatering of slurry can be achieved. This further allows for the removal of slurry storage compartments from operations which firstly pose environmental hazards and are also costly to construct. The text in this paper explores the basic principles of dewatering technology making use of plate and frame filter presses.

Anatomy of a plate and frame filter press

The plate and frame filter press consist of a number of concave filter plates stacked up against each other which, when assembled, form a series of cavities between each set of plates. This is illustrated in Figure 35.

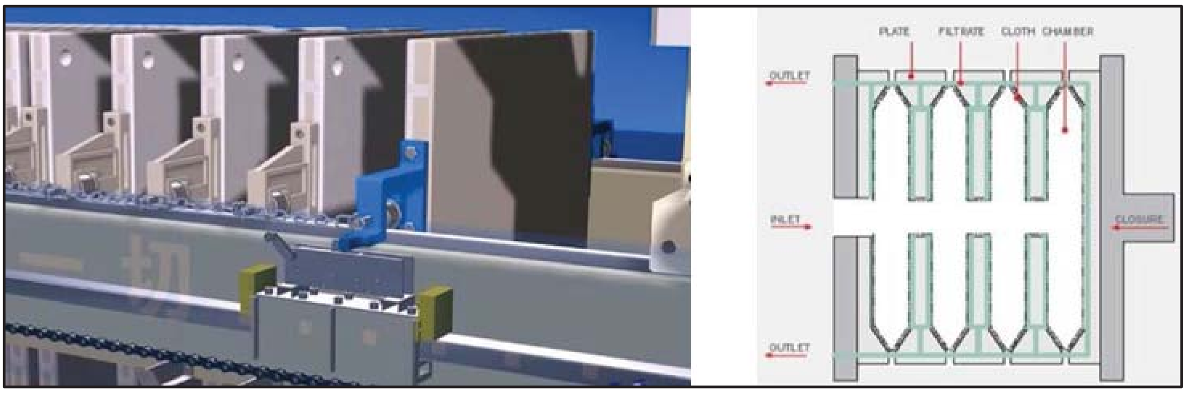

Figure 35: Plate and frame filter press showing, a) concave filter pates and, b) cavity that forms between successive plates (http://www.lenntech.com)

Each filter plate has a number of ports used for feeding of slurry and extraction of filtrate, these are indicated in Figure 36

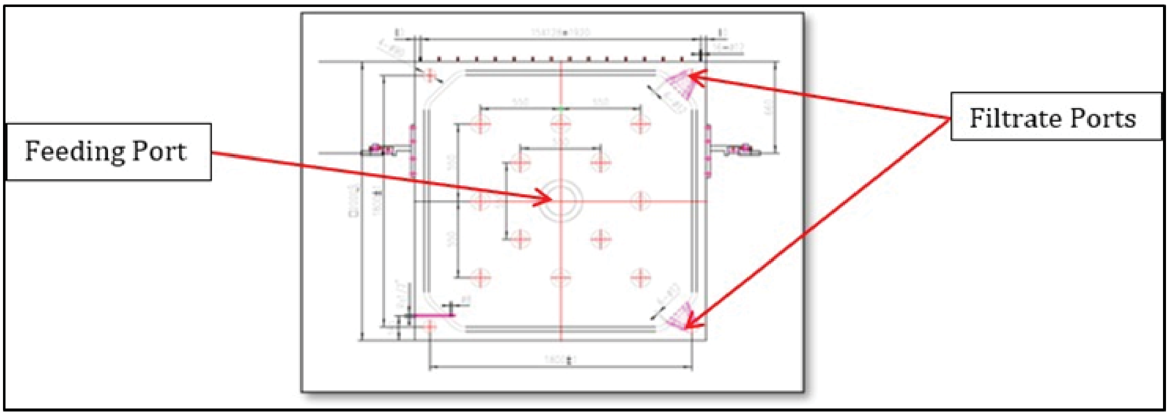

Figure 36: Filter press plate showing feeding and filtrate ports

The filter press receives slurry through the feed port whilst simultaneously extracting filtrate through the filtrate ports until the unit has been completely filled. It is noted that the plate and frame filter press operate on a batch processing basis. The filter press feeds from both ends simultaneously, reducing the time required to complete the filling step. Figure 37 shows the filter being fed from both ends.

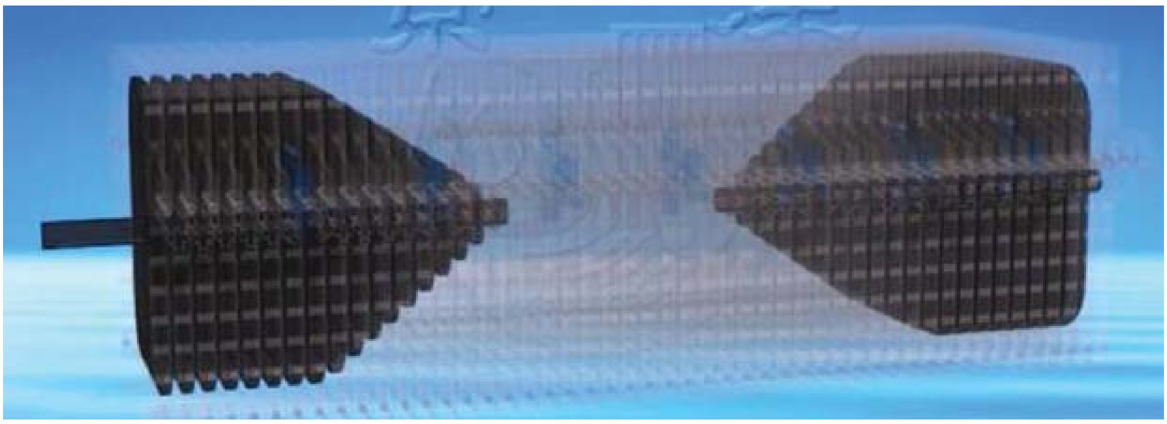

Figure 37: Filter press receiving feed from both fixed and movable head sides simultaneously

Additionally, the full-function plate and frame filter press incorporates a membrane squeeze functionality. The series of plates discussed alternate between recess plates and membrane plates. While the recess plate is a single, solids unit, the membrane plates consist of a solid core, covered with an inflatable cover. Pressurised water is then introduced between the core and the cover when the filter press is full, effectively squeezing additional moisture out of the filter cake already formed within the filter press.

In addition to reducing the cake moisture to a minimum, the compression of the filter cake caused by the squeezing functionality also ensures that a competent filter cake is produced in each cycle that the press completes.

Finally, these plates are held in place on slider, side bars on each side of the unit and the whole unit is completed by a fixed end and a movable head. The movable head is actuated through the use of a hydraulic cylinder. This hydraulic cylinder supplies the main compressing force during the filtration operation. The fully assembled plate and frame filter press is shown in Figure 38.

Figure 38: Fully assembled ENPROTEC plate and frame filter press

The filter cycle

The plate and frame filter press operates on a batch basis and a number of steps are included in the complete cycle. These steps are indicated in Figure 39.

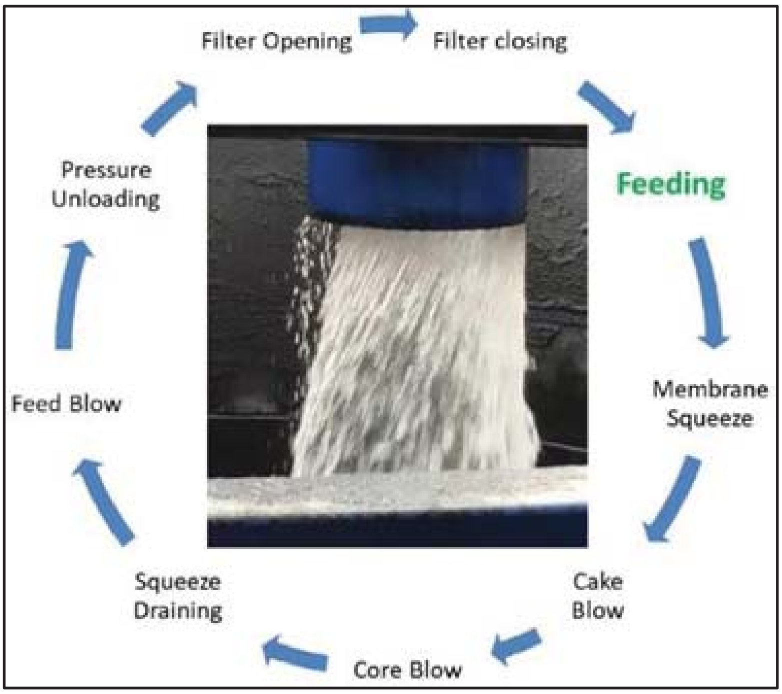

Figure 39: Steps included in the plate and frame filter press cycle

High pressure filter press technology

Development

Filtration and dewatering technology are not new concepts and have in fact been around since as early as 1600 BCE in China where oil was extracted from tea leaves (Kent & McGrew n.d.). But it was only during the industrial revolution in the 18th century that the mechanical filter press really started developing into the plate and frame filter presses that industry knows today. (Kent & McGrew n.d.). Jump forward another 300 years and highly efficient, plate and frame filter presses are being produced on mass scale to service all sectors of the mineral processing industry, from tailings discard sludges to high quality platinum and gold concentrates. In all instances, the filter press technology is reducing the complexity of slurry and material handling operations whilst simultaneously, greatly reducing the impact that our industries have on the environment. Further, in the past decade, ENPROTEC has, through the continuous development of filtration technology and innovative plant design, proven that tailings filtration is a cost-effective solution to tailings handling.

Technology overview

The driving principle of any dewatering operation is to separate solid particulate from the liquid carrier, this is achieved by introducing a slurry onto a membrane or surface of selective permeability. In this way, a dried filter cake is produced on one side of the membrane whilst the carrier liquid, or filtrate, is collected on the opposite side (Figure 40).

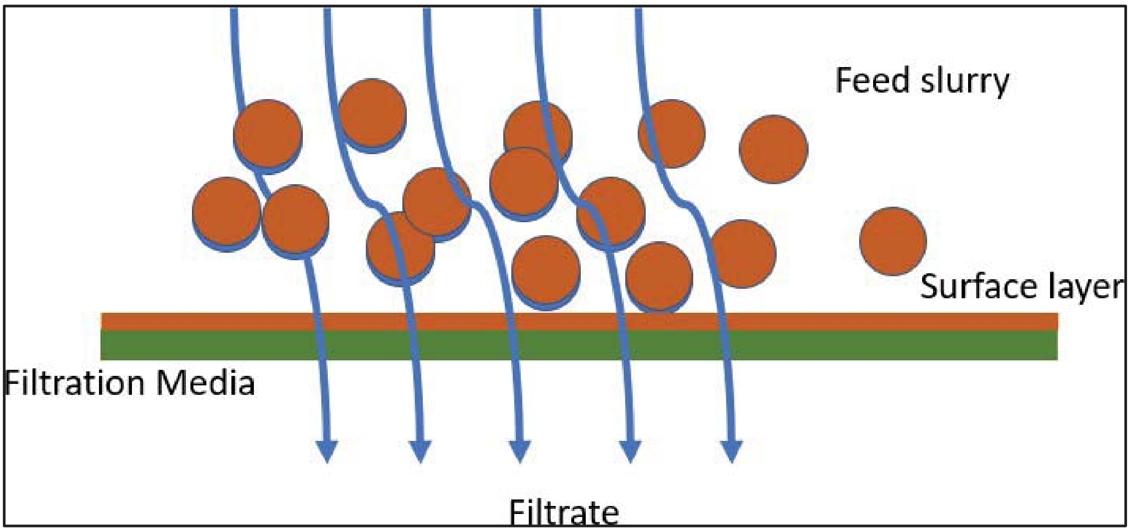

Figure 40: Filtration Principle – Selectively permeable membrane (ENPROTEC)

The image presented in Figure 8 alludes to one of the main considerations of the typical dewatering process, i.e. the resistance to fluid flow across the permeable membrane. This resistance is governed by two factors, namely:

- The permeability of the filtration media
- The filtrate resistivity within the forming filter cake on the surface of the filtration media

Dependence on filtration area

From the discussions made in this section, it can be concluded that the throughput tonnage per unit time of a filter press is dictated by the available filtration area, i.e. the more filtration area you have, the greater the hourly throughput becomes. Firstly, due to the limitation imposed by the filter media itself and secondly due to the formation of filter cake (a larger area allows for a thinner cake and therefore less restriction due to the forming filter cake). This has resulted in very large, flat filtration surfaces being incorporated into typical process plants which require large footprints.

The high-pressure plate and frame filter press addresses the need of large footprints by essentially folding the filtration media back on itself in the form of stacked filter plates. This allows for large filtration areas to be compacted into a small footprint.

Sizing and selection

The sizing and selection of a high-pressure plate and frame filter press is governed by two parameters, namely the Filterability of the material and the maximum Flux achievable for the specific application. These two factors have already been considered from a theoretical point of view and this section discusses the practical application of the theory in order to size a plate and frame filter press.

Material filterability and flux

The filterability of any given material is a measure of the throughput tonnages that are achievable per unit of time, given a set amount of filtration area. This parameter of filterability is measured as kilograms of dry filter cake producible per hour per square meter of available filtration area.

Filtration area is in square meters. Cycle time is in hours and encompasses all steps of the cycle as already discussed.

The filterability of a slurry is dependent on a number of factors such as the particle size distribution (PSD) and mineralogy of the particulate as well as the solids concentration of the feed slurry. These factors have a direct effect on the feeding time of the filter press and therefore affect the overall cycle time and, consequently, the filtration capacity.

Considering the effect of PSD on the filterability of a material, the graph in Figure 11 is presented. It can be seen that for any given ash content of the feed slurry (the effect of the ash content is further considered below), a finer PSD results in a higher final cake moisture. Considering then Equation 1, it can be seen that a higher cake moisture will result in a lower filterability. This effect can be ascribed to the filtration resistivity, i.e. a finer distribution of particles in the slurry results in lower permeability of the filter cake forming along the filter media. The higher resistance to flow through the filter cloth results in a longer feeding time to fill the filter press and therefore a longer cycle time and a lower filter throughput.

Taking a more detailed look into the mineralogy of the feed sample, the graph in Figure 12 is presented. Some minerals are known to be difficult to filter, such as coal ash, clays and mica. These minerals exhibit properties such as platelet morphology, hydration and swelling characteristics and surface charges which render them difficult to filter using plate and frame filters. The presence of such minerals therefore has an effect on the filterability a slurry. This effect is illustrated here.

Test work indicates that an increase in the ash content of the feed slurry results in a lowered filterability. It is of great importance to understand the make-up of the feed slurry, especially when considering the filtration of tailings materials as this type of material usually contains the discards of the process and therefore, large amounts of such material which is difficult to dewater.

The various factors that affect the throughput of a plate and frame filter press makes the sizing and selection of such units a fine balancing act between over-sizing for throughput and under-sizing for economic considerations. For this reason, test work is conducted to ascertain the exact properties of the material to be filtered.

Laboratory scale test work

Laboratory scale test work makes use of a small-scale replica of the full-scale filter press to conducted test work on. The filter completes all the steps listed for the filter cycle and a number of parameters are monitored. These parameters are:

- Full cycle time
- Filtrate extracted as a function of the filtration time
- Final cake mass and moisture

- Filter area used (this number can be changed by altering the number of filter plates used)

From this information gathered, the two parameters needed for the sizing of a filter press as discussed can be determined. The measured values are used to calculate the filterability of the material and the rate of filtrate collection is used to construct a Flux curve for the test work. A typical flux curve is shown in Figure 13.

Up-scaling for industry

From the results obtained during test work, the following calculations are made:

Filtration area required

The required filtration area of a filter is determined by knowing the required throughput tonnages as well as the filterability of the material to be filtered. The figures below illustrate the effect that the material's filterability has on the filter sizing.

Calculation of filtration area required

Required Throughput (t/h)	Material filterability ($kg/m^2/h$)	Filtration area required (m^2)
25	75	333.3

Scale-up factors

The scale up factor is a more complex consideration than that of filtration area requirements. Typically, the laboratory scale filter press will produce a filter cake which is thinner than that produced by a full-scale unit. Scaling the units up from laboratory scale to full scale therefore requires that consideration be given to the increase of filter cake thickness. Considering then again, the graph presented in Figure 13, it is seen that the initial filtration flux is high and then gradually decreases as the filter cycle continues (The flux is determined by the inverse of the slope of the graph between any two points). This is due to the filter cake building up against the filter cloth and increasing the filtration resistivity. When the laboratory filter test reaches conclusion, indicated by the last diamond indicator in the graph, the test is complete, and the filter cake has reached its final thickness. Should the available volume of the laboratory filter press allow for further filtration, it can be accepted that the flux curve will continue along the same trajectory and, as such, the graph is extrapolated.

This then indicates that additional cake thickness is directly linked to additional filter cake volume which needs to be added to the filter press. Further, the additional volume being added to the filter will produce and additional volume of filtrate which will be extracted. Therefore, with the additional amount of filtrate that will be produced being calculated and the filter flux being determined from the extrapolated graph, the additional feed time required to increase the cake thickness can be determined.

The new feed time can then be used to calculate the filterability, and finally, the required filter area can be determined as discussed.

Environmental benefits of slurry dewatering

It is all too easy to find traces and the effects of acid mine drainage and ground water pollution across South Africa wherever sulphide (http//www.dwa.gov.za) and sulphur containing mineral processing occurs. Environmental legislation is becoming increasingly strict and although mining houses and processing operators are heeding the call of cleaner operations, while such operations are not effluent free, they will likely continue to have a negative effect on the surrounding environment*. The impact on the environment, and our scarce water resources in specific, is two-fold. Firstly, when slurries are deposited in storage facilities, water will ultimately seep into the ground water table and result in pollution. A second impact is that of raw water required to keep a processing plant in operation. A typical mass balance is presented in Table 2 for the operation of a small coal DMS plant processing 250 tons per hour without any dewatering processes.

**It is noted that legislation now requires that all new slurry storage facilities be thoroughly lined with impermeable materials which prevents water from seeping into the ground water table. The costs for such lined storage facilities can easily add up to tens of millions USD, making the facilities uneconomical.*

Table 13: Typical coal DMS plant mass balance

	Dry tons (tph)	Slurry tons (tph)	Water (m^3/h)	Slurry volume (m^3/h)	Slurry RD (t/m^3)	Particle SG (t/m^3)	%Solids (w/w)
Feed to plant (-50 mm)	250.0	263.2	13.2	179.8	1.46	1.50	95%
Coarse Product (-50x1 mm)	138.1	157.0	18.8	110.9	1.42	1.50	88%
Coarse Discard (-50x1 mm)	74.4	84.5	10.1	59.7	1.42	1.50	88%
Fine Product (-1x0.3 mm)	13.0	17.6	4.6	13.2	1.33	1.50	74%
Fine Discard (-1x0.3 mm)	7.0	9.5	2.5	7.1	1.33	1.50	74%
Ultra-fines (-0.3 mm)	17.5	67.3	49.8	61.5	1.09	1.50	26%
Return water	0.0	29.9	29.9	29.9	1.00	0.00	0%
Make-up water required	0.0	42.8	42.8	42.8	1.00	0.00	0%

The numbers in the table indicate a make-up water requirement of 42.8 m^3/h (42,800 l/h). Over a typical month of processing, this adds up to 23,523 m^3 (23.5 million litres) per month and 282,278 m^3 (282 million litres) per year.

Filtration processes effectively recover water from the ultra-fines portion indicated in Table 2 and returns that to the processing plant. These addresses both environmental concerns discussed as no slurry is stored, thus eliminating the chance for seepage and water pollution and additionally, raw water requirements are drastically reduced. Considering a DMS plant that has dewatering technology in operation, the figures in Table 3 are presented. Similar to the first scenario illustrated by the figures in Table 2 where no dewatering processes are installed, the ultra-fines slurry is considered. In this scenario, this ultra-fine slurry is dewatered to produce a filter cake and the filtrate is re-introduced into the plant water circuit. This effectively reduces the amount of make-up water required. Table 3 indicates the potential reduction in make-up water that can be achieved.

Table 14: Reduction in make-up water requirements with the inclusion of filtration technology

	Ultra fines	**Make-up water required (without filtration)**	**Filter Cake**	**Filtrate returned**	**New Make-up required (with filtration)**	**Reduction in make-up water**
Dry tons (tph)	17.5	0.0	17.5	0.0	0.0	-
Slurry tons (tph)	67.3	42.8	22.2	45.2	27.5	-
Water (m^3/h)	49.8	42.8	4.7	45.2	27.5	36%
Slurry volume (m^3/h)	61.5	42.8	16.3	45.2	27.5	-
Slurry RD (t/m^3)	1.09	1.00	1.36	1.00	1.00	-
Particle SG (t/m^3)	1.50	0.00	1.50	0.00	0.00	-
%Solids (w/w)	26%	0%	79%	0%	0%	-

Thus, employing an effective dewatering process can typically reduce a coal processing plant's make-up water requirement by 36%. Additionally, it is noted that the filter cake produced has a sufficiently low moisture content to ensure that it can be placed on a conveyor system or handled with plant equipment. Not needing to place ultra-fine material in ponds for evaporation and further drying greatly reduces the footprint required by a processing plant to safely store tailings material.

Conclusions

In ENPROTEC's 10 years of operation, the company successfully designed, installed, commissioned and operated tailings filtration plants at more than 30 mineral processing facilities in Southern Africa. This has equated to millions of tons of ultra-fine slurry being filtered and billions of litres of water being saved. The capabilities that high-pressure plate and frame filter presses offers the industry has the potential to drastically alleviate pressure being placed on the environment. Further, the solution offered by these filtration units comes at a fraction of the price typically demanded by the licensing and construction of environmentally safe slurry storage facilities as all discard is of a dry nature.

The effective sizing, selection and operation of a plate and frame filter press has proven to be a viable solution to the treating of tailings slurry across all mineral processing applications. This type of technology improves materials handling and placement of fines, reduces raw water requirements and eliminates the need for slurry storage facilities.

In conclusion, the dewatering of tailings slurries offers a multitude of benefits, including:

- Production of a dry, conveyable and stackable tailings material
- Maximum water recovery from tailings slurries when compared to other dewatering techniques
- The latest technologies and modern innovative plant designs developed by ENPROTEC, achieves Capital Expenditure (CAPEX) and Operational Expenditure (OPEX) figures for filtration plants that is comparable to traditional thickening and pumping operations.

5.3 ADVANCES IN X-RAY SORTING TECHNOLOGIES

CASE STUDY 8: TOMRA SORTING SOLUTIONS

This case study documents the water conservation and demand management measures implemented by Tomra Sorting solutions. Tomra sorting solutions specialises in designing, manufacturing and maintaining sensor-based sorting technologies for the mining industry. Their sorting mining systems have been installed worldwide and has contributed to extending the life of mine of mining operations and increasing the value derived from deposits.

Their X-ray sorter has been one of Tomra's solutions biggest success stories. They have been implemented nationwide and have resulted in a higher throughput, reduced operational, labour requirements and environmental impact.

Description of Process:

Initially ROM coal/minerals are mined from mineral deposits. The ROM enters a preliminary stage where the ROM/minerals (substrate) particles are reduced. This stage involved the substrate being fed through a screen. The undersized particles are stockpiled at a material collection point stockpile where samples are taken. This ensures that the feed being sent to the XRT would allow for the separator to achieve a high operating efficiency. The feed conveyor I the XRT plant allows for uniform distribution of the particles. The x-ray screen within the unit separates particles based on their atomic density. This needs to be calibrated into the machine and is based on the type of mineral/ deposit being mined. The high-pressure air compressor is used to eject the number of contaminants within the feed stream. The ejection process results in two collection chambers a product and discard stockpile. Refer to Figure 41 for a description of the process carried out.

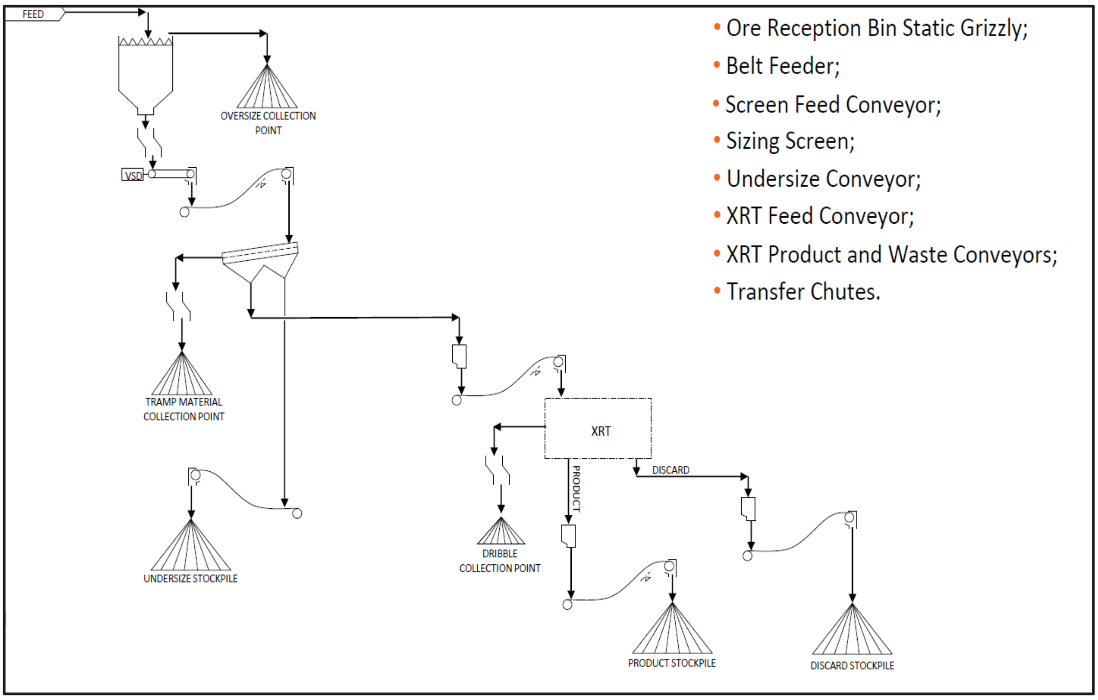

Figure 41: Process flow diagram

Benefits XRT Coal de-stoning

The XRT coal sorting has been implemented in South Africa at the Msobo, New Denmark and Matla coal mines. From their operations the following benefits were achieved;

- Dry and cost-effective ash reduction in coal
- Produces coal with a higher calorific value (CV) which intensifies the burning capacity of the coal
- Dry coal processing (Water has only been used for Dust suppression purposes)
- Results in increased feasible ore reserve
- Increased capacity
- Reduced energy consumption
- Reduced water consumption
- Less wear and tear
- Reliable technology

The following statistics show the content of Ash within the Feed to the XRT sorter, the ash content that was present after being beneficiated within the XRT sorter and the total reduced ash content.

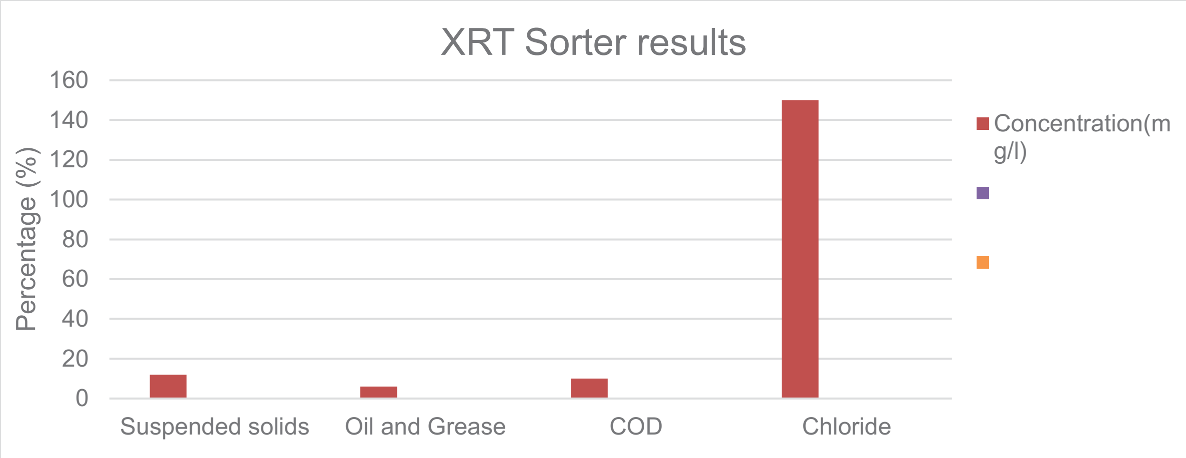

Figure 42: XRT Sorter results

Figure 42 displays the results received from the implemented XRT sorters at specific mines. From the results the most reduction of coal ash was noted for coal feed that is categorized as being low grade and a coal feed that is less wet.

Core Technology – Principle of sorting

The XRT sorter works on the principle of identifying objects, processing these objectbased on their material density and using air jets that either eject these objects into the product or discard chambers.

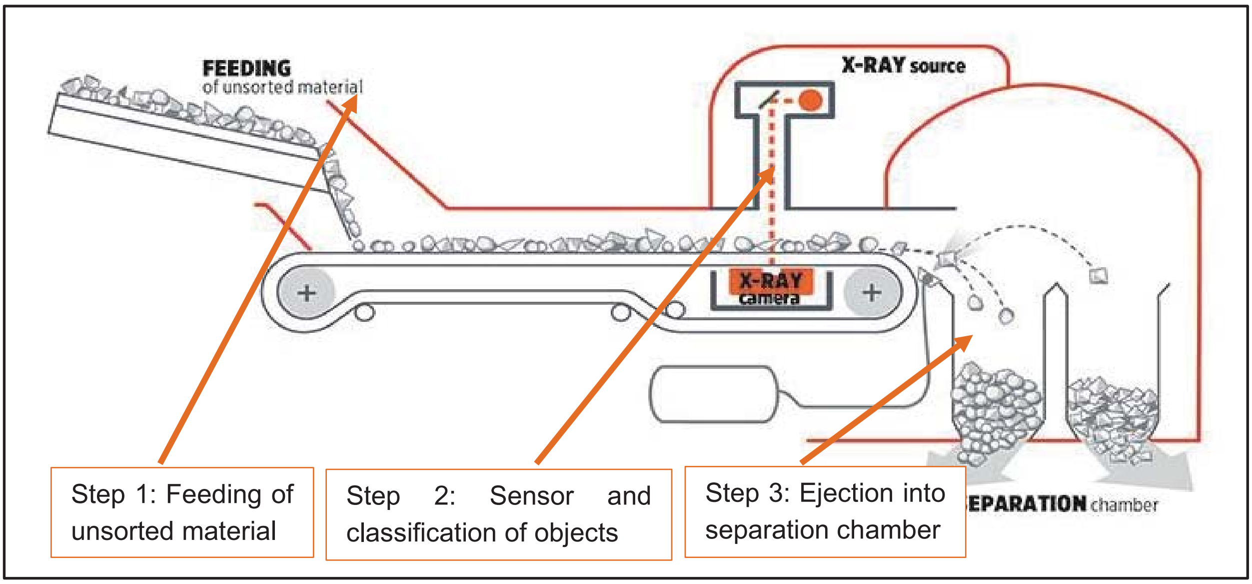

Figure 43: Principles of XRT Sorter

Capital and operating expenditure costs

The cost and design of the XRT sorter is dependent on the feed capacity. There are currently two XRT models available. Specifications of this model is shown in Table 15.

Table 15: Capex and Opex costs

Model:	Capex cost	Opex rate costs
COM XRT 1000	R11 500 000	R200-260/hour
COM XRT 2400	R18 000 000	R380-500/hour

Challenges faced

Feed preparation is important as this has an impact on the XRT efficiency. The feed should be uniform and have and over size and undersize of 2%. There should also be little, or no fines and the feed medium should be not too wet.

5.4 WATER TREATMENT TECHNOLOGIES

5.4.1 Case studies associated with water treatment technologies

CASE STUDY 9: DECREASE IN USE OF MUNICIPAL WATER BY TREATING MINE AFFECTED WATER TO POTABLE WATER STANDARDS

The mine included as part of this case study is a Gold Mine in South Africa that is serviced by two underground shafts. Water from the underground workings is stored in the surface concrete tank. Water from the underground workings is recycled from the concrete tank to the fridge plant, backfill plant and the Gold Plant.

Potable water to the mine is supplied by Rand Water and the South Shaft boreholes. In 2013/2014, the mine installed three Reverse Osmosis (RO) modules, one at the Fridge Plant, one at the Gold Plant and one at the Backfill plant in order to decrease the total RO usage. The mine does not abstract water from the River and no water is discharged into the environment.

The mine was looking to reduce the NWA section 21a water use charge and the total Rand Water charge. Another key objective was to improve the water recycling and re-use on the mine.

Table 16 shows the results of the WC/WDM calculations for the Mine for the past 7 years of operation and **Figure 44** shows a comparison of the Rand water, process mine water and RO water

Table 16: Key volumetric parameters associated with the underground water balance at the Mine

Year	GW ingress	Service water (total recycled in)	Water in vent air	Water from UG	Water out – Vent air	Potable water in UG	Total Rand Water inflow	South Shaft b/h	Total RO water
2011/2012	1954	10779	50	12264	518	1696	8530	107	0.00
2012/2013	1107	16464	50	17103	518	1700	6565	149	0.00
2013/2014	551	15906	50	15989	518	945	5307	415	1592
2014/2015	432	14231	50	14195	518	1220	3974	461	2117
2015/2016	1228	13167	50	13927	518	514	7437	423	2153
2016/2017	3191	10309	50	13032	518	775	4416	366	2126
2017/2018	2427	8576	50	10536	518	2814	4386	293	2852

All flows in m^3/d

	Consump-tive water use [m³/d]	Waste-water lost [m³/d]	Total specific water use [m³/tonne]	Consump-tive Specific Water Use [m³/tonne]	Percentage of total wastewater generated that is not reused	recycle ratio
Commodity Benchmark [9]			**2.09**	**2.02**	**60%**	**18%**
2011/2012	25 386	25 386	3.7	3.8	61	39
2012/2013	29 883	29 883	4.3	4.3	58	42
2013/2014	23 021	23 021	4.7	4.6	56	44
2014/2015	19 824	19 824	4.9	4.65	53	47
2015/2016	25 818	25 818	4.8	4.8	55	45
2016/2017	24 039	24 039	4.8	4.5	54	46
2017/2018	21 331	21 331	4.9	4.8	52	48

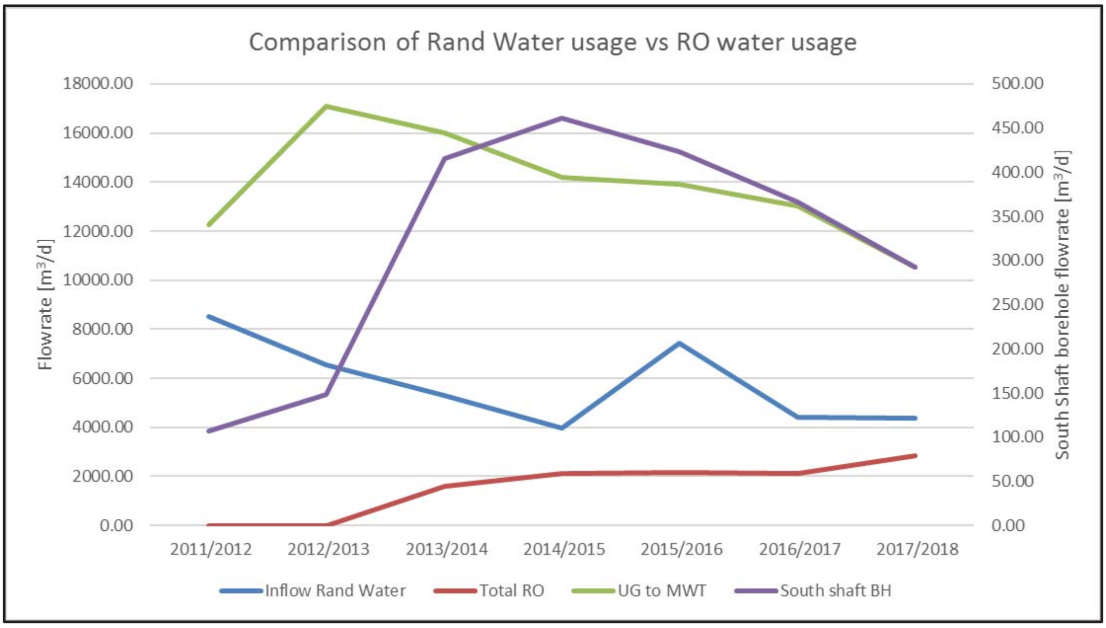

Figure 44: Comparison of Rand water vs RO water usage over the years

Figure 45 to Figure 47 shows the change in the WUE indicators over the last seven years of operation.

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[9] Source: "*Benchmarks for Water Conservation / Water Demand Management in the Mining Sector – Indicators and Commodity-based Water Use Efficiency Benchmarks*", DWS 2016.

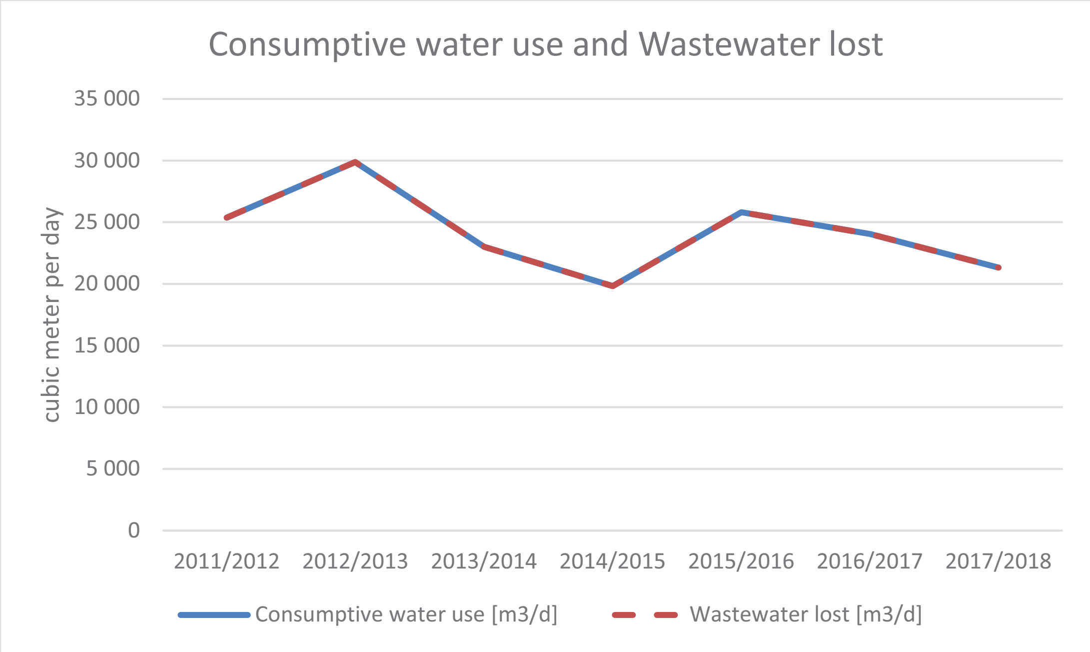

Figure 45: Consumptive water use and wastewater lost

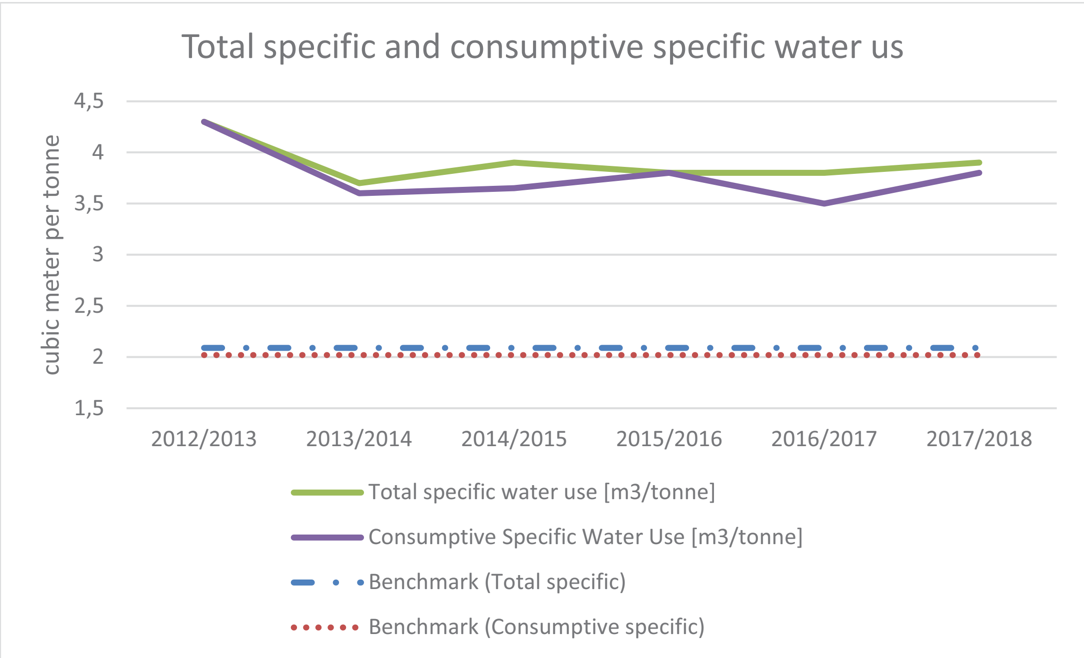

Figure 46: Total specific water use and consumptive specific water use

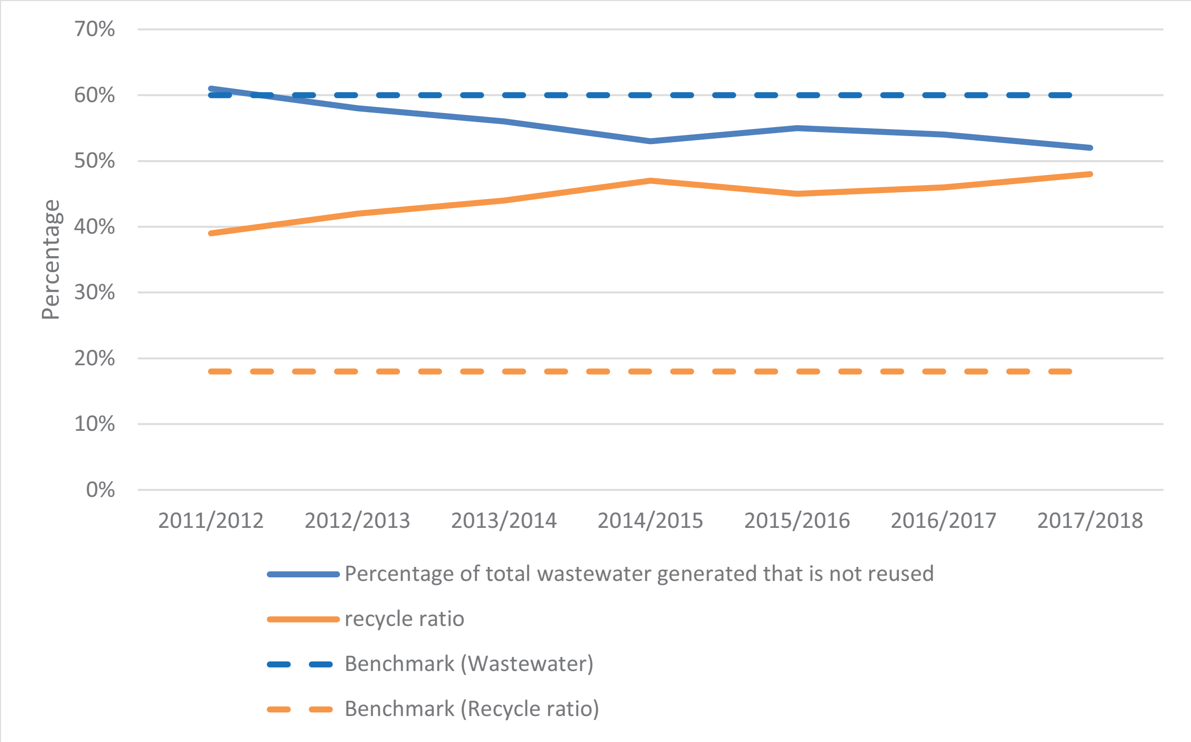

Figure 47: Percentage of wastewater lost that is not re-used and recycle ratio

Future considerations

The Mine produces between 500 m³/d to 1000 m³/d of treated sewage effluent. The current total Rand Water inflow is just under 4 000 m³/d. The mine plans to treat the sewage effluent further in the RO plant to potable water standards, thereby further reducing the total Rand Water supply to the mine. Figure 48 shows the comparison of total sewage effluent produced vs total Rand water used at the mine.

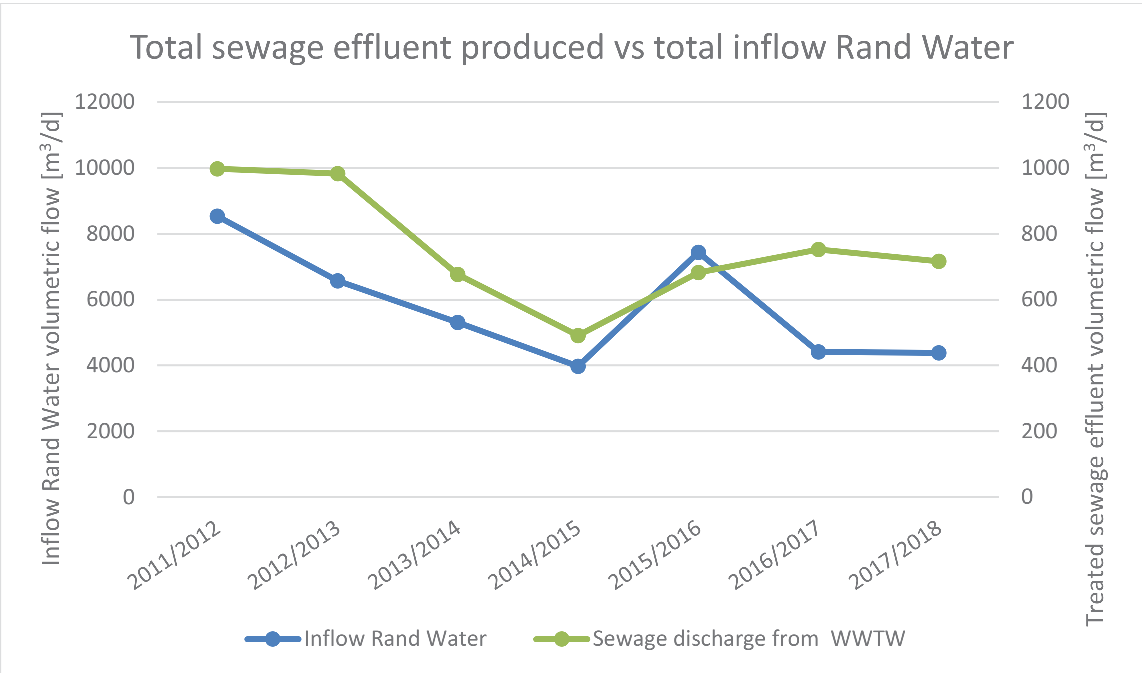

Figure 48: Total sewage effluent produced vs total inflow from Rand Water

Data assurances

The above information was sourced directly from data as collected and stored by the mine. The data used in the water balance is audited on an annual basis. The company is issued with a data assurance statement which is published on in the company's annual report. The audit consultant identifies and communicates key risk areas whose resolution is checked and verified in subsequent years.

CASE STUDY 10 – CRYSTALACTOR ® TECHNOLOGY – MINIMISING POTABLE WATER CONSUMPTION BY USING CRYSTALACTOR TECHNOLGY ® TO TREAT IMPACTED FISSURE WATER

This case study documents the water conservation and demand management measures implemented by the Mine W. The mines are located in the outskirts of Westonaria, Gauteng, South Africa. The decommissioned Mine supplies water to the adjacent mine. The impacted fissure water from the mines is softened, filtered and disinfected using Crystalactor® technology. The treated water is used as service and potable water for other existing operations, nearby farms and villages as well as, the Golf Club course. This initiative has resulted in the following benefits; (i) The plant has reduced their dependency on the Rand water intake by 50%, (ii) The Crystalactor plant produces a solid-liquid interphase that consists of liquid contaminant free water and solid crystallised pellets (iii) the technology results in a zero liquid discharge (ZLD) system which creates an ease in disposal of solid waste.

GENERAL CRYSTALACTOR INFORMATION

Crystalactor is a technology that purifies water using a crystallisation technique, while harvesting valuable resources from the water. It is used for both drinking water and (industrial) wastewater for removal of a large number of heavy metals and other inorganic compounds. The Crystalactor technology has been developed and maintained by Water Care Mining (WCM). WCM have specialised in water treatment services throughout South Africa. Their biggest accomplishment thus far has been the Crystalactor plant that has been installed at Mine W.

Process description of how the Crystalactor works

The heart of the Crystalactor installation is the pellet reactor, partially filled with a suitable seed material such as sand or minerals. The wastewater is pumped in an upward direction, maintaining the pellet bed in a fluidized state. In order to crystallise the target component on the pellet bed, a driving force is created by a reagent dosage and pH-adjustment. By selecting the appropriate process conditions, co-crystallization of impurities is minimised and high-purity crystals are obtained. The pellets grow and move towards the reactor bottom. At regular intervals, a quantity of the largest fluidized pellets is discharged from the reactor and fresh seed material is added. After atmospheric drying, readily handled pellets are obtained and the need for sludge dewatering or hauling of sludge is eliminated. Due to their excellent composition, the pellets can often be recycled or reused.

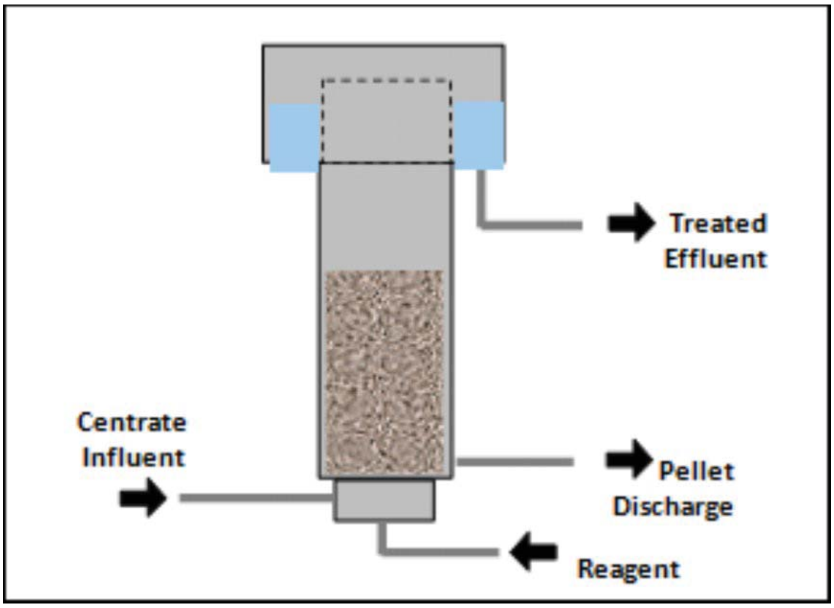

Figure 49: Crystalactor Technology operating principle

Chemistry of the Crystalactor

The Crystalactor chemistry mimics the conventional precipitation. By dosing a suitable reagent to the water (e.g. lime, calcium chloride, soda, caustic soda (NaOH)), the solubility of the target component is exceeded and forms a solid crystal substrate. The primary difference with conventional precipitation is, that in the crystallization process the transformation is controlled accurately and that pellets with a typical size of approx. 1 mm are produced instead of fine dispersed, microscopic sludge particles.

Application of the Crystalactor technology

The technology can be used in most mining industries to treat mine impacted water. The treated water from plant can be reused as potable, process or service water for mining operations. The quality and properties of the influent are represented in Table 17. This indicates a preliminary screening technique that can be used to determine if this technology will be applicable to a specific mine.

Table 17: Application properties for the Crystalactor plant

Property:	Industry typically found:	Initial concentration range (ppm):	How it is removed in the Crystalactor ®:	Treated final quality (mg/l):
Calcium Hardness	All mine applications	xxx	Calcium from water is removed in the form of calcium carbonate pellets by dosing lime, caustic soda or soda ash as softening reagents	The final concentration of hardness in the effluent stream is approximately 20 mg/l

Property:	Industry typically found:	Initial concentration range (ppm):	How it is removed in the Crystalactor ®:	Treated final quality (mg/l):
Fluoride recovery	All mine applications		Fluoride from water is removed in the form of calcium fluoride pellets by dosing lime, or a combination of caustic soda and calcium chloride as reagents	The concentration of the fluoride can be reduced below 10-20 mg/l
Phosphate recovery	All mine applications		Phosphate from water is removed **in** the form of calcium phosphate, magnesium phosphate or struvite (magnesium ammonium phosphate) pellets by dosing lime or magnesium hydroxide, or a combination of caustic soda and magnesium chloride as reagents	The phosphate concentration can generally be reduced to 0.2-0.5 mg/L. Effluent filtration is usually required to remove suspended phosphate flocs that are present as carry over from the reactor
Heavy Metal Recovery (HMR)	Industrial wastewater and Mine water	HMR flows with metal concentrations between 50-2000 mg/l	HMR can be recovered as metal carbonate or hydroxide pellets by dosing a combination of caustic soda and soda ash as reagents. The bulk of the HMR is removed in the form of pellets from the reactor. The required low effluent concentrations are usually achieved by recycling the reactor effluent several times, depending on the initial concentration.	The metal concentration can generally be reduced to below 1 mg/l

Description of Process AT Mine W

Mine W is a shallow to intermediate gold and uranium mine that has been commissioned since 1961. The operations are situated in the West Wits Line of Witwatersrand Basin near the town of Randfontein. The operations consist of four vertical production shafts and two gold processing plants. The operations also include the underground workings area, an active tailings mining retreatment operation and Surface Operations. The underground workings were placed on care and maintenance during 2017.

The underground fissure water from both operations are softened using the Crystalactor® technology adapted and designed by Water Care Mining (WCM). The current mining method used at the Mine W is TM3 destress cut with drift and bench mining and backfill support as well as conventional breast mining.

Treated water from the Crystalactor technology has been used as service and potable water for nearby operations, communities and farms. The consumption rate of these providers is unknown and will need to be confirmed by the mine.

Impacted fissure water from the underground operation is pumped via a WCM pump station to the Crystalactor® plant which is located outside the current mine footprint. The pump station has a pumping capacity of 30 ML/D. The impacted water is pumped through the bottom of the three Crystalactor® columns (two operational and one on standby). The upward feed direction of the wastewater helps maintain the pellets within the fluidised bed. To allow for surface absorption and crystallisation of the calcium and heavy metals, Silica sand is used as a seeding material. The sand is mixed with a hydrocyclone prior to being fed within the Crystalactor® column. The silica crystals that form after surface absorption are discharged at the bottom of the column. At regular intervals, a quantity of the largest fluidized pellets is discharged from the reactor and fresh seed material is added. After atmospheric drying, readily handled pellets are obtained and the need for sludge dewatering or hauling of sludge is eliminated. Due to their excellent composition, the pellets can often be recycled or reused. Caustic is added to soften the impacted water. The clear water effluent that exits the top of the column has a high pH and the pH is adjusted by adding acid. The clear adjusted effluent from the column is then sent to a series of activated carbon filters. This is to reduce the organic content that may be present in the effluent. The treated water from the filters are sent to potable water tanks where disinfection takes place. The treated water is then stored and directed to the town reservoir. Prior to being sent to the reservoir regular samples are taken to make sure that they are on spec. A lab on site ensures that efficient and reliable testing takes place. If the water quality does not meet the SANS 241 specification the line is redirected to the backwash tank where it is retreated.

Other elements include two RO modules that are used to treat some of the impacted water which is used as caustic make up water which is added to the column.

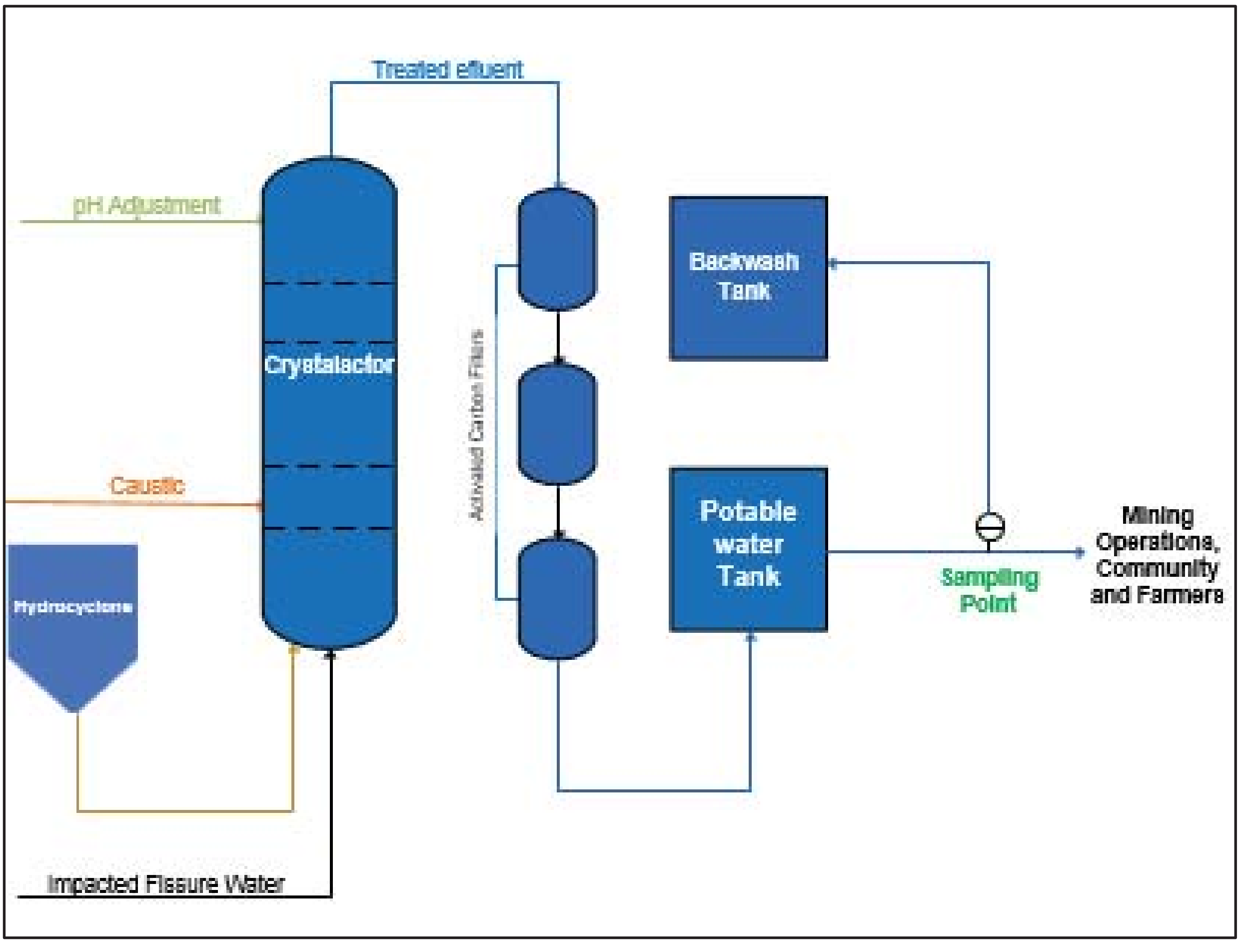

Figure 50: Simplified process diagram of Crystalactor plant at Mine W plant

Site visit observations

The Crystalactor site visit took place on the 14th of August 2019. Upon our preliminary investigation and analysis, it was noted that the plant was small and compact and consists of 3-4 working personnel at a time. The plant conducts on site analysis that measures water quality to see if the effluent being consumed by the community is with specifications.

The driving force for the Crystalactor technology at the plant was the reduction of potable water from rand water. The benefits of the Crystalactor technology over conventional RO and IX water treatment is discussed below;

- **No Residual Waste**: There is no brine waste produced and the system produces a Zero Liquid Discharge (ZLD) in the form of fluidised silica pellets that can be dewatered and disposed of safely (refer to Figure 2).
- **Cost Effective**: The Crystalactor is also a cost-effective solution that constitutes to a reduced payback period.
- **Compact**: It is also a small efficient compact unit. As the four process steps found in conventional precipitation processes – coagulation, flocculation, sludge/water separation and dewatering – are combined into one by the fluidized bed crystallization.

Figure 51 below displays the silica particles before and after surface absorption has occurred. The before indicated particles are normal silica sand which is fed through the bed and acts as a seeding medium. The after particles show a swollen like dry pellet that has allowed for the absorption of calcium hardness and heavy metal absorption. The pellets are dewatered and discarded in a nearby waste facility. The pellets are inert and stable and are classified as being a level 4 hazard waste.

Figure 51: Silica Particles after and before surface absorption

The Crystalactor ® water treatment plant location would not have an impact on the core production of the mine. It can be located within the mine boundary and does not have any other physical changes to current operations aside from a pump station that may be required to direct the impacted water from the mine to the water treatment plant.

Water savings

It was stated that this initiative reduced the community's reliance on potable water from Rand Water by 97%. The Crystalactor water treatment plant also reduces the community's reliance on potable water from Rand water as it supplies a sufficient amount of water to its third-party users. The plant produces on average 5000 m^3/day of potable water.

Table 18: Percentage reduction

	2014	2015	2016	2018
Rand Water Consumption (m^3/day)	5460	6900	100	233
Water treatment plant supply (m^3/day)	*	*	3500	2926
% Reduction	*	*	98%	96%

Table 19 summarises the quarterly production data, water and consumption and the total cost of purchased water. All these factors are directly proportional to one another, as the one factor fluctuates so does the other.

Table 19: Summary of quarterly production, water consumption and cost of water consumption per month.

Year Quarter	Year quarter production (Mton)	Water used to process ore (Ml)	Cost (ZAR)
October-December(Q4) 2016	1.11	498	5 251 595
January-March(Q1) 2017	1.21	478	5 032 754
April-June(Q2) 2017	1.14	596	6 792 001
July-September (Q3) 2017	0.97	556	7 023 192
October-December(Q4) 2017	0.41	493	8 296 308
January-March(Q1) 2018	0.69	509	3 776 113
April-June(Q2) 2018	1.03	465	5 773 593
July-September (Q3) 2018	1.15	415	5 592 160
October-December(Q4) 2018	1.22	400	5 298 489
January-March (Q1) 2019	1.17	406.86	3 890 234

The figure below trends the relationship between the water consumed and the cost associated with it for each quarter.

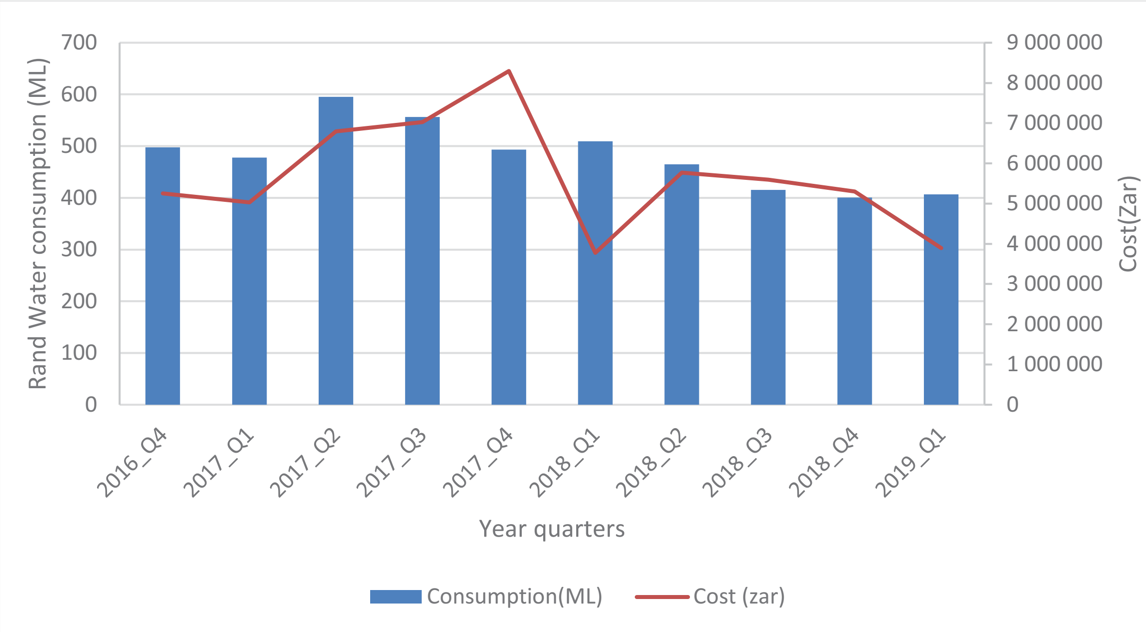

Figure 52: Relationship between Water consumption and Cost

Figure 52 displays the overall consumption of the potable water purchased at Mine W. The increased consumption noted for December 2016-June 2017 is a result of an increased requirement from suppliers, various disruptions in the pipeline network (such as burst pipelines and vandalism to existing infrastructure) and pump breakdowns/control system failures at the supply line. The lower consumption during the rest of the review period is a result of the leakages fixed at the as well as the installation of the control system. The pumping system was also replaced in October 2017 which further influenced the reduction of the consumption levels. By fixing the vandalised pipelines there was an improved control at the Crystalactor® water plant. The plant was implemented in 2016 and there has been an almost 25% reduction in the reliance of water from Rand Water.

Challenges faced

The operations are under care and maintenance and are easily exposed to theft and vandalism. The infrastructure within the plant are also old and dilapidated which result in a lot of pipe leakages.
Water use efficiency indicators are shown in Table 20.

Table 20: Water use efficiency indicators for Mine W

Indicator	**Water use efficiency values**					**Industry Benchmark**	**Unit**
	Average	2014	2015	2016	2018		
Total Water used	76581	78892	79830	73400	74202		m^3/d
Consumptive water used	75080	73990	79030	73240	74060		m^3/d
Volumes of water lost	60537.5	21420	74530	72140	74060		m^3/d
Total Specific Water use	0	0	0	0	0	2.09	m^3/tonne
Consumptive Specific Water Use	0	0	0	0	0	2.02	m^3/tonne
Percentage of total wastewater generated that is not reused	26%	10%	30%	31%	34%	60	%
Recycle Ratio	0.67	0.65	0.68	0.69	0.66	0.18	
New water inputs	74042.25	78160	77400	72800	67809		
Recycled water inputs	154988.8	146090	168050	161730	144085		
Calculated water inputs	2538.75	732	2430	600	6393		
Consumptive water uses	33464.75	3100	54460	68740	7559		
Non-consumptive water uses	1501	4902	800	160	142		

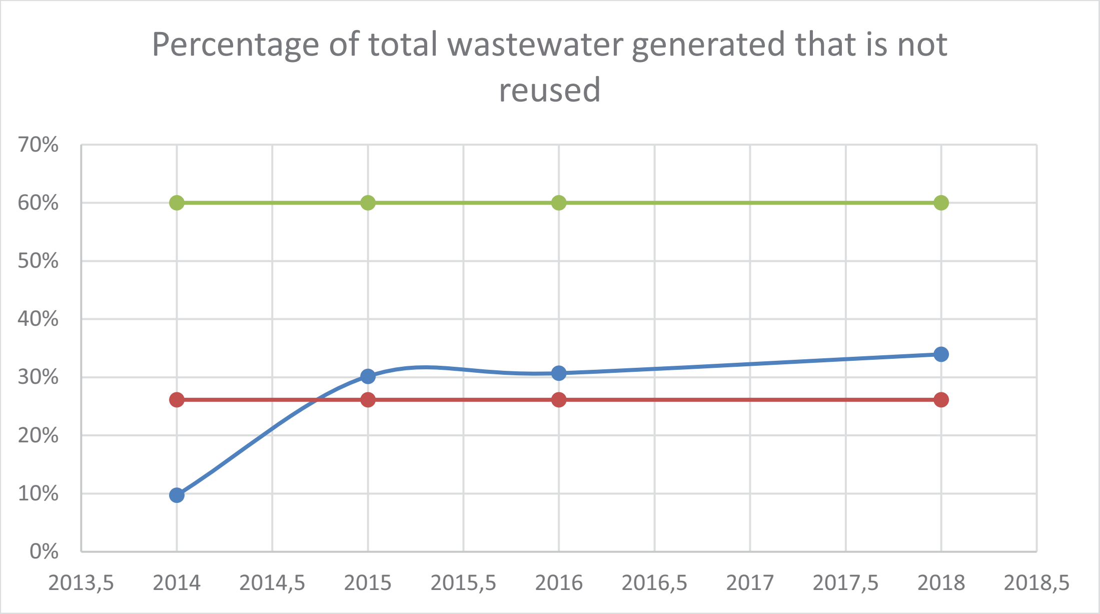

Figure 53: Percentage of total wastewater generated that is not reused

Figure 53 displays a percentage of the total wastewater that is generated but not reused. The statistics for 2014 are the lowest for the review period. The percentage of total water unused is far lower than the national benchmark. Which indicates a reduction in the consumptive water uses and recycles streams.

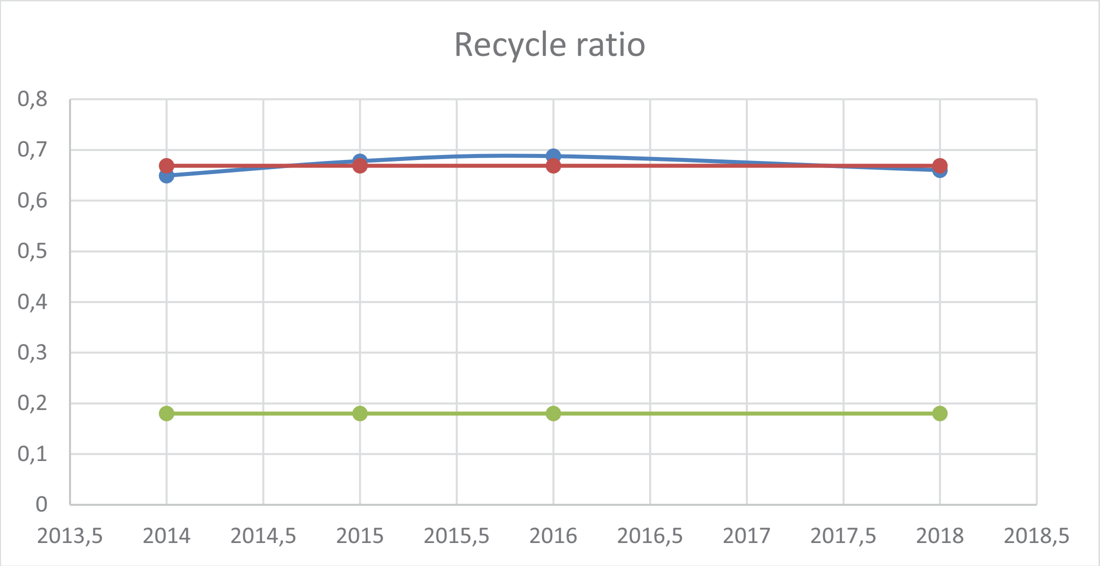

Figure 54: Recycle ratio for Mine W

Figure 54 displays the recycled ratio for Mine W. The recycle ratio shows a reducing trend, however, it is much higher than the national benchmark of 0.18. This indicated that there is an increase the total volume of water lost from the mine.

CASE STUDY 11: ION EXCHANGE (IX) – MINIMISING POTABLE WATER CONSUMPTION BY USING IX TECHNOLOGY TO TREAT IMPACTED FISSURE WATER

This case study documents the WC/WDM measures implemented by the Mine X located in the Witwatersrand Basin, South Africa. The mine has recently implemented an Ion Exchange (IX) plant that softens impacted fissure water which is used as potable and service water. This initiative has made the mine less dependent on the intake of Municipal water reducing the overall stress of water supply within the catchment.

Ion exchange is an advanced process that is responsible for removing dissolved ions, calcium and magnesium from the feed stream. There are several suppliers that specialise in installing and maintaining IX units within South Africa. Water care Mining (WCM) is one of these suppliers that are responsible for IX units within South Africa as well as abroad. The IX type that is most beneficial to water softening is the down-flow or packed column type.

Process description of IX

The Ion Exchange process is generally coupled with a pre-treatment step. This step is mandatory as suspended and colloidal matter will form at the surface of the bed, thereby increasing the pressure drop. As a result, channelling is usually encountered and portions of the bed are bypassed. The effluent from the pre-treatment is pumped into the ion exchange unit.

The exchange medium consists of zeolites (natural occurring material) or synthetic resins that are responsible for the mobility of impurities from the influent water. The ion exchange process consists of a resin regeneration tank that consists of either sodium or potassium salt. This ensures that the resin facilitated throughout the unit is not exhausted. Most IX plants have a resin regeneration unit that contains either sodium or potassium salt which assists in salvaging spent resin. Refer to Figure xx for a simplified diagram of what occurs within a typical IX unit.

Water Chemistry associated with IX

When contaminants dissolve in water they usually form ions. Ions are electrically charged portions of a compound. In natural occurring waters there is a balance between positive (cations) and negative (anions) charged ions. When contaminants are dissolved within natural occurring water, they have an impact on this balance. If the contaminant is a cation it can be removed by a cation exchange resin. If the contaminant is an anion the appropriate treatment media would be an anion exchange resin (EFS, 2009).

Application of IX Technology
Ion Exchange is advantageous for the following reasons:

- Flowrates

Most Ion exchange systems are limited by flowrate for hydraulic reasons such as pressure loss through the resin bed. As a precaution measure the flowrate through the ion exchange membrane should not exceed 49 m^3/hr (Wachinski, 2006). At higher flowrates, the pressure exerted on the resin bed, together with the thermal and osmotic stresses, is insufficiently large to begin breaking some of the resin beads. The intended flowrate of brine through the ion exchange membrane is approximately 12 m^3/hr (single train). Given any area of the ion exchange membrane the flowrate will be much lower than the exceeded flowrate. This favour the application of Ion exchange for the intended system.

- Sulphate Removal

Sulphate ions are preferentially removed over other bivalent and monovalent ions. The intended feed quality to the ion exchange unit has a capacity of 3355-9336 mg/l of sulphates. Due to the selectivity of the bed towards sulphates, ion exchange should be investigated further.

<u>Description of Process:</u>

Mine X is a mature shallow-deep level gold mine that commissioned gold production in 1952. It is located in the West wits line of Witwatersrand Basin, in the Gauteng province of South Africa. Climatically the area has no extreme changes in temperature and rainfall that influence mining activities. Mine X has nine shaft complexes (one tertiary shaft and three sub shaft systems) and a single mineral processing plant.

Description of IX process
The impacted water from the shafts are directed to the IX water treatment plant. The treatment plant consists of a pre-treatment section and the IX unit. Table 3 shows an estimate of the expected water quality from the shafts.

Table 21: Mine X water quality (Botha. M., 2009)

Element	Concentration(mg/l)
Suspended solids	12
Oil and Grease	6
COD	10
Chloride	150
Sulphate	1140
Calcium	210
pH	7.5
Conductivity	2300
Uranium	0.234

The pre-treatment unit consists of a dissolved air flotation unit (DAF), preliminary disinfection, sand filters and granular activated carbon filters (GAC). The DAF unit assists with the removal of partial solids and oil and grease that may be present in the influent stream. The preliminary disinfection step uses sodium hypochlorite which increases the free chlorine levels within the influent stream this reduces the microbiological growth within the impacted water. The Coagulating Sand Filter assists in the removal of suspended solids as well as colloidal uranium that may be present. The GAC unit removes any dissolved organic (DOC) compounds that may be present. The pre-treatment section is present upstream to protect the delicate ion exchange membrane from suspended solids, organics, oil and grease which can not only damage the membrane but poison the resin and reduce the overall efficiency of the unit (Botha. M., 2009).

The pre-treated effluent proceeds to the uranium ion exchange section. The IX configuration consists of two lead columns (operational/standby mode). The main aim is to reduce the uranium concentrations below 20 ug/l. The lead columns contain the resin. The next step is the polishing column that contains the same resin which ensures that a further reduction in the uranium concentration is achieved. The columns operate as packed beds in an up-flow direction with counter current regeneration. During regeneration sulphuric acid is used to clean the lead columns (Botha. M., 2009).

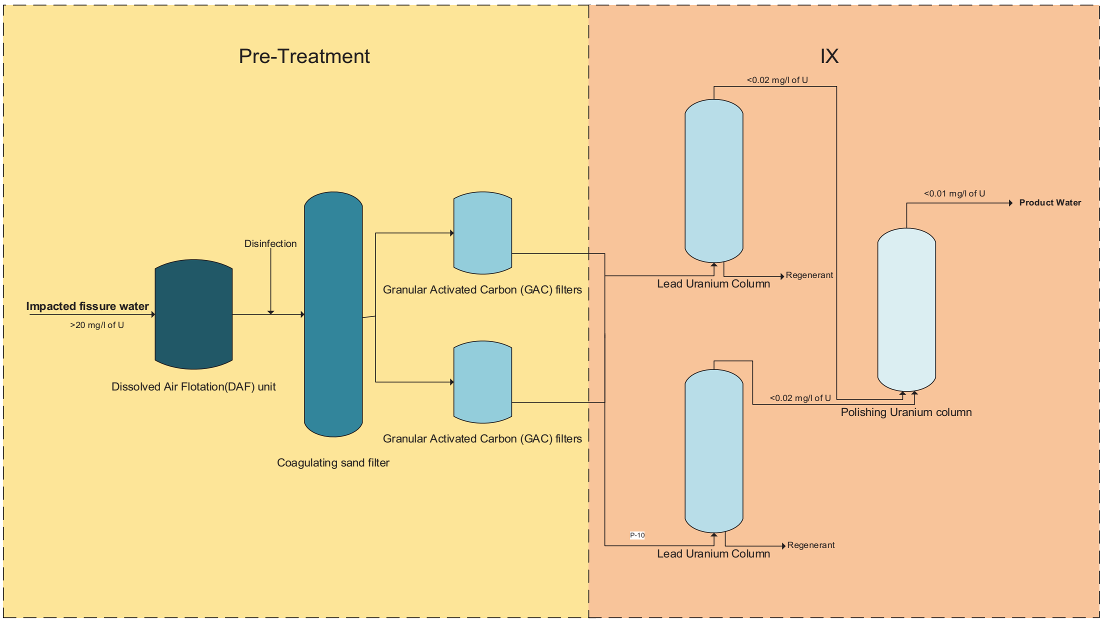

Figure 55: IX process flow diagram ((Botha. M., 2009)

Water conservation

Introduction

The current mine infrastructure consists of six operational shafts. The IX treatment plant allows for treatment and blending of the underground impacted fissure water. The water treatment plant produces 20 ML/d of drinking water for the Mining Complex. The unique IX regeneration resin allows for a lower reagent consumption. This resin had to have a high selectivity for the uranium compound so that the resin will have a greater retention time. This allows for reduced reagent consumption which is proportionate to reduced costs. The overall estimated savings amounted to R1.5million/month.

Company X's approach to a WC/WDM strategy began by identifying the area in the Mine X2 which consumes the most amount of potable water. This was identified as being the west village area which consumes an estimated 4413915 Ml/year. A further look into this area revealed that its biggest consumers are its production plant – which uses 800 kl/day, its compressors and fridge plant cooling towers and the cement factory and its potable water consumption.

The other problem that was identified was the traces of uranium that was present in the cooling and process water. The uranium contaminated process water is finally discharged onto the tailing storage facility from where it is leached and returned to the water system causing a uranium buildup.

The first initiative, defined as the automated metering system, was implemented in 2016. The idea behind this was to create a water management system that can be controlled and that detect any leakages within the pipelines.

The second initiative – defined as the implementation of the IX plant was commissioned in 2016. This initiative was meant to originally reduce the amount of uranium within the discharge stream. This will help with the WUL compliance as well as return cleaner water to the catchment. The mine has also used this water in their process operations as process water and cooling water in their fridge plant to reduce the cost and consumption of potable water. Initially a pilot plant was built up to test the efficiency of removing the uranium form the water.

The IX initiative

The mine is dependent on two sources, water from Rand Water Municipality and Fissure water from their mine operations. The Pie chart in Figure 56 below identifies the amount of water abstracted from these sources. Majority of the water abstracted is from the underground operations.

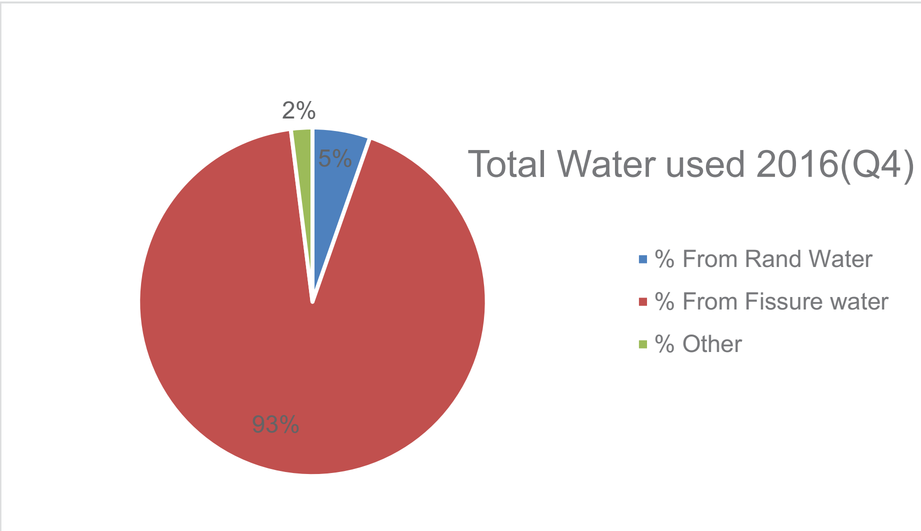

Figure 56: Representation of water abstracted from sources (October-December 2016)

Water savings

It was stated that a total of R1.5 million/month is saved by implementing these initiatives. The table summarises the quarterly production data, water and consumption and the total cost of purchased water. All these factors are directly proportional to one another, as the one factor fluctuates so does the other.

Table 22: Summary of quarterly production, water consumption and cost of water consumption per month.

Year Quarter	Year quarter production (Mton)	Water used to process ore (Ml)	Cost (ZAR)
October-December(Q4) 2016	1.39	8343.96	6 710 334
January-March(Q1) 2017	1.38	8438.97	8 543 139
April-June(Q2) 2017	1.53	9269.68	12 359 133
July-September (Q3) 2017	1.64	8814.23	7 710 217
October-December(Q4) 2017	1.49	8843.03	5 442 976
January-March(Q1) 2018	1.32	8426	5 227 654
April-June(Q2) 2018	0.84	8843.49	6 710 300
July-September (Q3) 2018	0.58	8185.66	8 758 355
October-December(Q4) 2018	0.04	8173.39	7 771 793
January-March (Q1) 2019	0.04	7526	4 716 155

The figure below trends the relationship between the water consumed and the cost associated with it for each quarter.

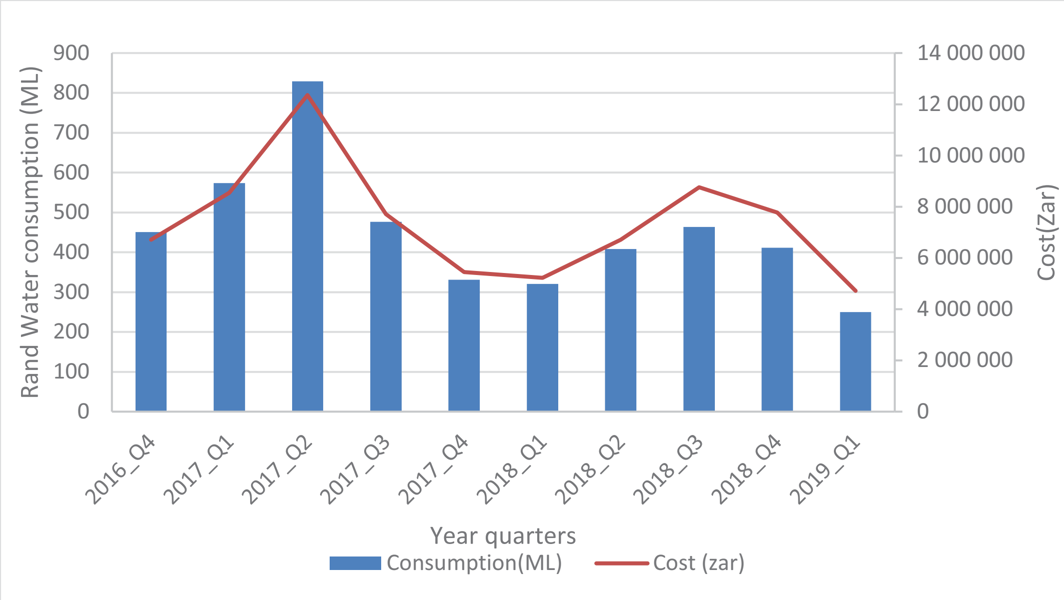

Figure 57: Relationship between Water consumption and Cost

The bar graph and line graph in Figure 57 represents the consumption (ML) and cost (ZAR) respectively. The relationship between the consumption and cost are dependent variables. The earliest review period was recorded in October 2016. During 2016 Q4 up until 2017 Q2 there was a large increase in the consumption of water. This can be accounted for by the contaminated fissure water and breakdowns within the filter plant which resulted in excessive amounts of purchased water. The highest peak of the graph is for the second quarter of 2017. The trend shown after this quarter shows a reduced amount of potable water purchased. This can be accounted for the implantation of the IX water plant as well as the automated metering devices. Softened water from the IX process plant was returned to the process plants and mining operations. This resulted in a reduction in the total amount of water required from the municipal. A further reduction can be accounted for by the monitored automated metering system that was implemented by the mine. This system helps to assist in leak detection as well as monitor the areas in the mine where the most amount of water is required.

Challenges faced

The biggest challenge faced by the mine was the implementation of the full-scale IX plant. The capital and investment costs for this type of technology was high. The other challenge was the implementation of the automated metering system as they had to be strategically placed to achieve proper water management. The other operational challenges include suspended solids that get clogged. This may occur due to improper primary treatment. When this does occur operation at the water treatment

Water Use Efficiency

Water use efficiency indicators are shown in Table 23.

Table 23: Water use efficiency indicators for Mine X

Indicator	Unit	Water use efficiency value						Industry Benchmark
		avg.	2014	2015	2016	2017	2018	
Total Water used	m^3/d	144294.8	149347	127910	133850	153649	156718	
Consumptive water used	m^3/d	95195.6	6247	110510	116150	135105	107966	
Volumes of water lost	m^3/d	114517.6	77197	118980	124720	143725	107966	
Total Specific Water use	m^3/tonne	492662.9	497823.3	426366.7	382428.6	529824	626872	2.09
Consumptive Specific Water Use	m^3/t	323758.1	20823.33	368366.7	331857.1	465879	431864	2.02
Percentage of total wastewater generated that is not reused	%	22%	13%	20%	24%	27%	24%	
recycle ratio		0.75	0.80	0.79	0.75	0.72	0.68	
New water inputs		116883.8	120400	117510	110380	109552	126577	
Recycled water inputs		444796.6	609757	473310	404580	397728	338608	
Calculated water inputs		27411	28947	10400	23470	44097	30141	
Consumptive water uses		78810.4	41800	102360	95970	113676	40246	
Non-consumptive water uses		49099.2	143100	17400	17700	18544	48752	

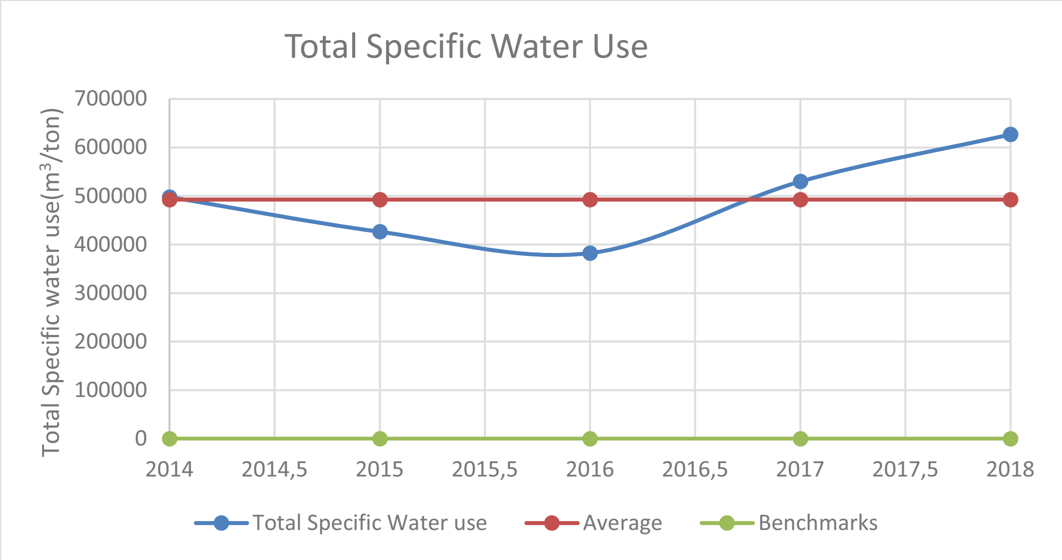

Figure 58: Total Specific Water Use

Figure 58 shows a reducing trend from 2014-2016. It increases substantially after 2016. The statistics for 2018 reveal that the total specific water use is 626872 m^3/ton. This indicates that the total water used per production is much higher. This increasing trend seems to be consistent and may remain the same for 2019 statistics. The total specific water use is much lower than the national benchmark.

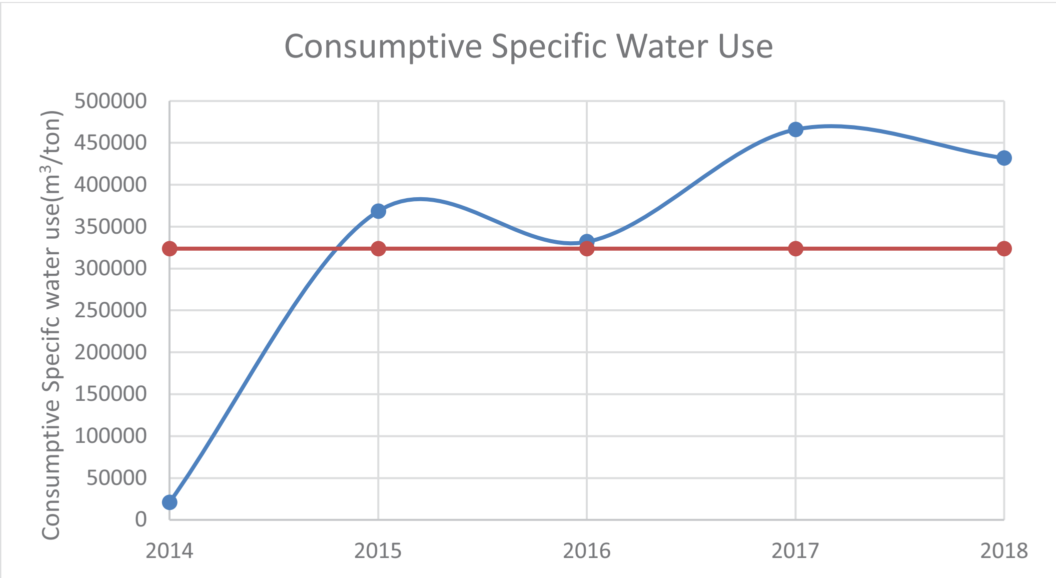

Figure 59: Consumptive Specific Water Use

Figure 59 displays an unsteady trend for the above review period. There is a significant increase from 2014-2015. It reduces in 2016 before increasing steadily for 2017. The 2018 results indicated that the there is a reduction in the consumptive specific water use. This shows that there is a reduction in the consumptive water used for production. This reducing trend may be predicted for 2019. The total specific water use is much lower than the national benchmark.

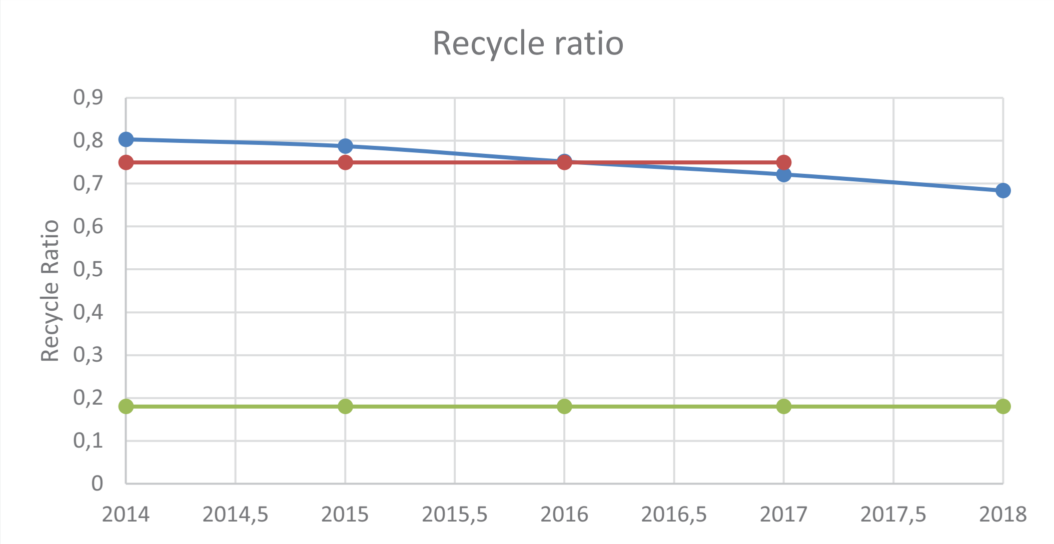

Figure 60: Recycle ratio

Figure 60 displays the recycled ratio for mine. The recycle ratio shows a reducing trend, however, it is much higher than the national benchmark of 0.18. This indicated that there is an increase the total volume of water lost from the mine.

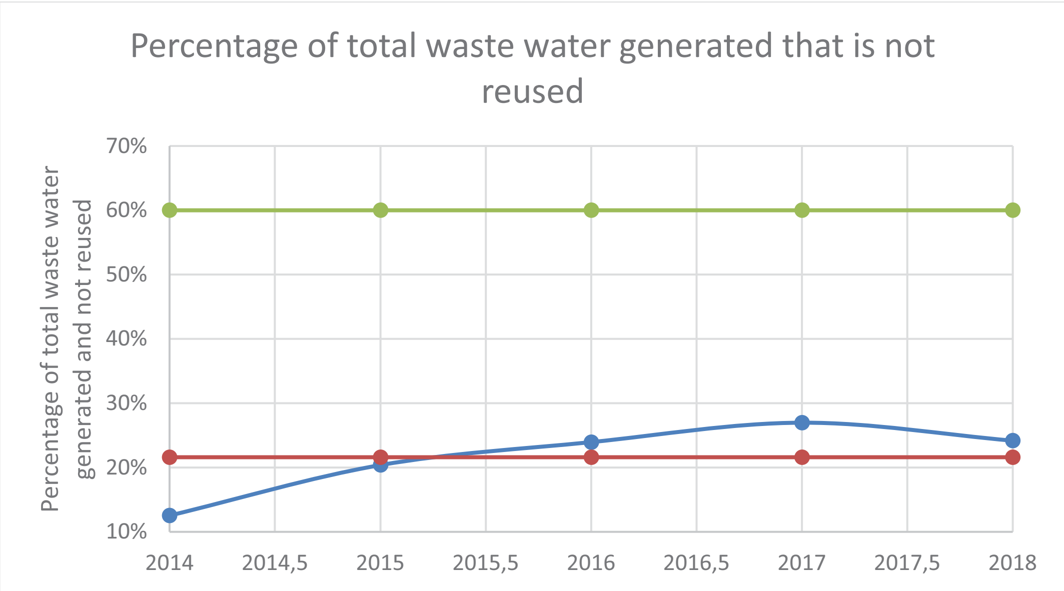

Figure 61: Percentage of total wastewater generated that is not reused

Figure 61 displays an increasing trend. This trend is significantly lower than the national benchmark. Which indicates a reduction in the consumptive water uses and recycles streams.

CASE STUDY 12: EMALAHLENI WATER RECLAMATION PLANT (EWRP)

Anglo American continuously strives to achieve responsible water stewardship, including recycling as much water as is possible a measure to mitigate the strain on the country's water resources.

One of their initiatives includes the construction and operation of the eMalahleni Water Reclamation Plant (EWRP). The EWRP is the only mining initiative to be endorsed by the United Nations Framework Convention on Climate Change (UNFCCC) Momentum for Change Initiative at COP 17 in 2011.

The plant was created on the principles of sustainability to ultimately help address long-term climate adaptation risks and promote a sustainable future for the region, providing better flexibility and self-sufficiency in terms of water usage. The plant effectively addresses operational challenges resulting from rising mine water levels and recycling polluted water into the environment.

Water is purified to potable quality by RO and is then sent on for use by various nearby Anglo-American mines and to the eMalahleni Local Municipality. The plant currently meets around 12% of the water-stressed local municipality's water requirements through the supply of 16 million litres a day into the Municipal reticulation system. The eMalahleni Water Reclamation Plant has treated in excess of 70 billion litres of water, 50 billion of which have been sent to the municipality with the rest reused within Anglo American's coal operations.

Contributing mines include Anglo American's Landau, Greenside and Kleinkopje Collieries, as well as South32's defunct South Witbank mine. Together these mines currently supply up to 30 million litres of water to the plant on a daily basis.

The EWRP treats water from a number of different sources including active and old defunct mines. The different mine water sources contain ammonia from natural geological sources and residues of explosives and fertilisers. It is also postulated that ammonia forms as a by-product during oxygen deficient spontaneous combustion and the burning of coal.

EWRP is effective in the removal of acidity and salinity and produces a high-quality product water. A wide range of salt specifies is removed, including partial removal of ammonia in the UF/RO process. The reclaims water, however, still contains a residual of ammonia. The question is frequently asked about the potential impact of ammonia on the health of the downstream aquatic ecosystem in the Naaupoort Spruit and on the drinking water users in Witbank.

CASE STUDY 13: FREEZE CRYSTALLISATION AND EUTECTIC FREEZE CRYSTALLISATION

Eutectic Freeze Crystallization (EFC) is a promising low temperature desalination technique that can retrieve salts in pure form from the saline waste streams, at a relatively low energy demand. Freeze crystallisation is advantageous for the following reasons (University of Cape Town News, 2018);

- There is zero liquid waste.
- It has a small footprint and is environmentally friendly.
- The process is less energy intensive compared to thermal evaporation. Energy requirement can be reduced by 75 to 90% as the latent heat of fusion of ice is 333 kJ/kg and that of evaporation of water is 2,500 kJ/kg (Heist, 1979) – although thermal evaporation process can also be designed to be very energy efficient by making use of energy recovery;
- EFC plants currently piloted on two coal mines in South Africa for the treatment of brine are proving to be successful. One is a PROXA Plant while the second one is a Prentec plant. This is based on discussions with the suppliers and colleagues consulting at the two mines.
- Ease of operation and maintenance based on discussions with suppliers.

Figure 62: EFC unit at the Tweefontein Colliery in Mpumalanga

Figure 62 illustrates the Tweefontein Colliery in Mpumalanga. This was the first full scale working unit for freeze crystallisation purchased by Glencore, designed and constructed by Prentec. Another application of this technology is at New Vaal Colliery.

At the time of writing this report, data for the analysis of this case study for both mines was not available.

5.4.2 Passive and Semi-Passive Water Treatment Considerations

There are currently no passive and semi-passive treatment options examples conducted that will provide compliant water qualities for discharge into the water resource.

To mitigate high costs related to active treatment methods, passive (and semi-passive) methods can be investigated. Passive water treatment systems are advantageous since they require little or no input of reagents, active maintenance or mechanical devices (INAP, 2009). These treatment systems are particularly ideal for decommissioned sites and the treatment of seepage where the temperature, chemical composition and the flow rate are relatively optimal and do not fluctuate all year round. When these passive systems are functioning properly, they can produce compliance level effluents with no additional costs apart from the initial construction and limited periodical maintenance. Some sites might require supplementary chemical treatment to meet effluent limits, but this too can be done in a cost-effective manner (Kuyucak, 2002).

Phytoremediation is a proposed passive treatment strategy that uses green plants to treat and control wastes in water, soil, and air. The strategy has been investigated and implemented as a pilot project at the Roy point mining operation. A semi-passive approach was implemented at the Union Colliery, with the installation of a barium carbonate-disperse alkaline substrate (BDAS) water treatment pilot plant, at the Butte Adit. The sections below provide a summary of the passive and semi-passive treatment options currently employed at two of South Africa’s leading coal mining operations that are currently closed.

CASE STUDY 14: UNION COLLIERY – BARIUM CARBONATE-DISPERSE ALKALINE SUBSTRATE (BDAS) PLANT

Barium carbonate-disperse alkaline substrate (BDAS) pilot water treatment plant has been implemented at the South32 Union Colliery. In South Africa Mine Drainage is characterised by a wide pH range from acidic (2.6) to alkaline (8). The ore host rocks contain mainly pyrite and carbonates, relating to AMD with high salinity (Ca>Mg>Na), hardness, metal concentrations (Fe^{3+} > Al^{3+} > Mn^{2+}) and moderate to low trace metal concentrations (Ni^{2+} > Zn^{2+} > Cu^{2+}). The conventional passive chemical treatment systems based on $CaCO_3$ and MgO neutralisation processes are not completely effective since the acid mine drainage treatment by $CaCO_3$ and MgO allows neutralisation and removal of metals but increases the salinity and hardness in the treated effluent; The low solubility of $CaCO_3$ at high pH levels also means that it can only be used as an acid treatment and not alkaline treatment option. $BaCO_3$ has been shown to have good dissolution rate between pH values of 0-6.5. At an optimum ratio to volume of water, $BaCO_3$ was shown to remove up to 50% salinity and conductivity. A final product of $BaSO_4$ sludge with moderate to low metal concentrations was reported, which could be recycled and used by other industries (Castillo *et al*., 2015).

The BDAS water treatment pilot plant was put in place following commitment to Inkomati Usutu Catchment Management Agency to resolve current pollution of surface water resulting from interaction with decant deriving from the Union Mine. The plant (capacity = 7.2 m^3/day) was commissioned in January 2017 and was contracted to be operated by the University of the Free State.

Advantages and disadvantages of the BDAS treatment method

The BDAS plant has the following advantages:

- The plant utilises simple technology and it can be operated and monitored remotely.
- The plant has low capital and operational costs.
- Low manpower and labour requirements for plant operation.
- The plant can be run purely on solar energy.
- There is the possibility for the wastes emanating from the plant to be reclassified to allow disposal as general waste or for re-use purposes.

The BDAS plant has the following disadvantages:

- The technology is still unproven on a large scale, although pilots have been run at a number of mine sites.
- Barium carbonate is imported mainly from China, where prices of the product are influenced by exchange rates, and delays have been experienced in getting the product on site.
- The University of the Free State holds patents and licences over aspects of the plant.
- Negotiations and agreements will be required to implement a full scale plant, which could cost more money; and the current Resource Quality Objectives (RQO) are extremely stringent (RQO for Electrical Conductivity is 30 mS/m, and Sulphate is 30 mg/l). These RQO's largely removes the semi-passive technologies from possible water management options to be considered.

Results from the pilot plant

The initial scope of work at the pilot plant investigated whether the plant was using appropriate technology compatible with current mine water quality and quantity, and if the technology was robust enough, and economically feasible to treat and clean contaminated mine water at the Union Colliery. The plant was operational for six months (January 2017 to July 2017) at a cost of R2 013 967.47. The plant was only operational during the day as it relied mostly on solar power and had no backup power supply. It was concluded in the first phase that the plant experienced a high amount of standing time in the barium and calcite reactors due to the limited solar energy, with the treatment limited to 1 500 to 2 000 litres per day. Water quality results were reported to be "promising" although not completely compliant to the whole spectrum of resource water quality variables. An upgrade of the plant increased the flow rate to 7 200 litres per day but results still reported exceedances in electrical conductivity and sulphate and barium concentrations. The pilot phase, however, showed that the system was able to restore pH and remove metals. Removal of Ca, Zn, B, Al, Mn, Ni and Fe was consistently high, showcasing the stability of the system. Mg, Cl and Na concentrations were not affected by the system.

Further investigations are to be conducted to improve understanding of 1) results of toxicity testing and testing mitigations related to the management of barite at the outflow, 2) the saleability of the by-product, 3) blending of the water qualities as a possible mitigation to the uncontrolled release of barium, 4) the development of a standard operation procedure (SOP) for the management of the system to prevent the unacceptable levels of barium in the solutions after treatment, and 5) a detailed cost estimation to upscale the pilot plant at the Colliery.

CASE STUDY 15: ROY POINT COLLIERY – PHYTOREMEDIATION PILOT WATER TREATMENT STRATEGY

Phytoremediation is the process of cleaning up contaminants from soil and water using plants. Phytoremediation involves growing plants in a contaminated matrix for a given time period, to assist in the degradation and eventual breakdown and immobilization of a contaminant. Phytoremediation can be applied in terrestrial and aquatic environments as a preparative or finishing step in clean-up technologies. The method can be used to clean up metals, pesticides, solvents, explosives, crude oil, hydrocarbons and landfill leachates (Ahalya and Ramachandra, 2006).

As part of the water management strategy at Roy Point, six trial plots with three tree species were planted to intercept runoff and also extract some of the groundwater. Species planted include *Eucalyptus dunnii* (White gum), *Searsia lancea* (Karee) and *Tamarix usneoids* (Wild tamarisk) since these are known to have high evapotranspiration potential. A monitoring program was implemented to motivate for further use of the trees and objectively evaluating phytoremediation as a feasible option as part of a suite of tools to support long term mine water management. The effectiveness of trees as a remediation option is dependent on the monitoring and water uptake rate to evaluate changes over a given time period.

Advantages and disadvantages of the BDAS treatment method

Phytoremediation has the following advantages:

- Phytoremediation is fundamentally driven by sunlight, thus making it publicly acceptable and cost-effective.
- Phytoremediation benefits soil stabilisation, biomass production and carbon sequestration These features improve cost-effectiveness and add to sustainability and public perception; and
- Plants treat lands without having a negative impact on the topsoil, thus maintaining and/or improving the soil utility and fertility, enhancing organic matter, nutrient concentration and biological activity.

Phytoremediation has the following disadvantages

- Phytoremediation is considered to be a slow and seasonal remediation method.
- Phytoremediation is restricted to the rooting depth of remediative plants.
- The use of invasive, non-native species can affect biodiversity.
- Harvested plant biomass produced from the process of phytoextraction may be classified as hazardous waste, therefore subject to proper handling and disposal; and
- Unfavourable climate can limit plant growth and phytomass production, thus decreases process efficiency (Rao and Babu, 2014).

Results from the pilot plant (Agreenco, 2019)

Findings from the pilot phytoremediation project at the Roy Point mine showed low soil moisture content and sap flow rates. This was related to the generally low rainfall rates resulting in low soil moisture content and less water for the trees to absorb in the area during the first quarter (November 2018 to January 2019) when monitoring was carried out. Higher rainfall was experienced after this period, however, and is expected to significantly contribute to an increase in soil moisture throughout the area. The data obtained from the observed time period was reported to be insufficient to accurately draw substantial conclusions regarding the planted trees. Data collected over a longer time period and different seasons will provide data sufficient enough to draw concrete conclusions regarding the efficiency of the implemented remedial system.

Discussion

Efficiency of treatment systems at these mines is of concern since there are no proven water quality results that are compatible with drinking, agricultural and aquatic water uses. The estimated amount of R1,5 million for the completion of the work at Union colliery are still related to a pilot project. If the results from this pilot project are not satisfactory, additional work will still need to be conducted. Phytoremediation options currently employed at the Roy Point mine are part of a cost-effective, environmentally friendly alternative to traditional clean-up methods. Successful implementation and monitoring of this system will ensure a successful treatment option. The success of this treatment method can, however, differ when implemented at the Klipspruit colliery due to climate differences and possible soil character differences.

Proper classification and understanding of the pilot projects at these mines can help in the determination of the best possible passive (and semi-passive) water treatment applicable to the Klipspruit mining site. The successful implementation and maintenance of these systems could prove to be a viable option for treatment of water at Klipspruit on a trial basis.

5.5 LOW-COST DRY TAILINGS DISPOSAL

Water sent to tailings disposal often represents the largest water loss at a mine. A tailings facility consists of the fine particles from mining. These fine particle slurries are difficult to dewater, and the current dry disposal methods have high capital and operating costs. An alternative approach involves combining course particle flotation to concentrate the mineral. Dry stacking has also become a phenomenal concept. Dry stacking technologies has been used to dewater residual waste and producing dry stackable tailings. It works on the principal of allowing particles to float at sizes that are two/three times larger than normal making it easier to extract water from the process, leaving behind a waste stream that is dry and stackable. These initiatives are low cost methods that will minimise the amount of water sent to the tailings facility.

- Condensation technologies for reducing water lost with ventilation air in underground mining.
- Construction of thickeners at heights greater than normal (45 to 60ft) results in a slurry (pulp) that is of a higher density (65-75%) which increases the concentration in the weight of the tailings by about 8% as compared to conventional high efficiency thickeners (which typically save 15% water).
- Create “stilling basins” so that their surface area is minimised to reduce water loss by evaporation. Stilling basins are areas of free-standing water that are formed in tailings impoundments when the tailings are deposited and settle out.
- This should be accomplished so that the rate of decant water recovery is increased
- Decant towers, barge pumps or sump pumps may be used to recycle the water back to the mill concentrators.
- Increase the capacity of the decant towers or barge pumps to enhance the recycling of the reclaimed water.
- Maximise the use of water from the tailings impoundment so that use of new groundwater is decreases.

CHAPTER 6: CASE STUDIES OF BEST PRACTICES IN WC/WDM

6.1 INTRODUCTION

Best practice is defined in various different ways. The Google, Merriam-Webster and Oxford dictionaries defines a best practice in exactly the same way, i.e. "*commercial or professional procedures that are accepted or prescribed as being correct or most effective"*, whereas, Cambridge dictionary defines best practice as an officially accepted working method or set thereof that is the best to use in a particular business or industry. All these definitions have one thing in common and that is a formal agreed upon approach to most effectively or correctly perform a certain aspect.

The DWS has promulgated various guidelines over the years that highlights best practices that are to be adopted.

6.2 SOUTH AFRICAN CASE STUDIES

6.2.1 Generally applicable best practices across the SA mining industry

This section and sub-sections that follow briefly describes some best practices that have been observed to be practiced across the South African Mining industry.

6.2.1.1 Best Practice 1: Use of instrumentation for monitoring and measuring key water parameters

Monitoring and measurements should not only be restricted to sources of supply and discharges but should be adequate to inform and calibrate a well compiled and managed water balance. Monitoring and measurement system should incorporate a database capable of storing electronic records throughout the life of the operation. This will assist in the analysis of historical water consumption to evaluate the change in water usage over time.
The system should include level detection on all water storage and containment facilities for the purposes of:

- Informing and calibrating the water balance;
- Recording spillages and troubleshooting;
- Determination of water losses; and

- Planning especially for the rainy season to avoid spillages.

Leak detection is required to manage risks and prevent losses in a timely manner. Adequate monitoring and measurement systems allows for planning and taking preventative measures and avoids situations that may lead to emergencies such as water shortage.

6.2.1.2 Best Practice 2: Water balance

A detailed water balance for the entire mine operation is imperative for implementing WC/WDM in a mine. The water balance allows mine personnel to understand the site-wide water management and allows for:

- The regular checking of water reticulation circuits;
- The review of current system operating procedures;
- The analysis of miscellaneous water usage and reduce/optimization thereof; and
- The identification of areas of water losses that can be recovered for re-use or reduction of water losses.

Regular update of the water balance is important to update the water metrics that are reported to management to manage water on site.

6.2.1.3 Best Practice 3: Recycling as much water as feasible

Using water from concentrate thickeners, tailings thickeners, tailings impoundments by constructing appropriate drainage and transportation. An example is solution trenches around a tailings storage facility to catch any seepage. This seepage can be returned back to the operation for re-use where appropriate. Tailings transportation systems should be designed to ensure no blockages and leakages occur.

6.2.1.4 Best Practice 4: Optimal storm water management infrastructure

One of the best and simplest WC/WDM measures that can be implemented is the optimization of clean and dirty water catchments. There should be a thorough investigation on how dirty catchments can be reduced to prevent clean rainwater from becoming contaminated and also reducing the total amount of “new” water into a facility.

6.2.1.5 Best Practice 5: Leak detection and prevention

Another simple way of saving on water losses is by preventing leaks. Many mines have old water reticulation systems that are leaking. Some of these pipes/pipelines are sub-surface and therefore the leaks cannot be physically observed. It is therefore important to implemented measuring and monitoring devices at key areas to detect if the system is leaking and fix these leaks. Regular inspections on the water reticulation system is important to ensure no leaks are forming.

6.2.1.6 Best Practice 6: Use of alternative sources of water

In some cases, alternative sources of water that do not affect downstream water uses can be sought. The copper mines in Chile are utilising desalination technology to render seawater usable for the mining operations.

6.2.1.7 Best Practice 7: Minimisation of runoff into surface water dams around the residue disposal areas

A simple way to minimise "new" water is to minimise the surface run-off around residue disposal areas. The return water dam should ideally only receive the penstock from a tailings facility. All areas surrounding the tailings facility and the return water dam should be operated as clean catchment areas.

6.2.1.8 Best Practice 8: Dewatering boreholes

Dewatering boreholes (depressurisation boreholes) can be drilled around a mining operation to intercept clean water prior to this water entering a mine pit and being contaminated. This water can be discharged directly into the environment thereby reducing the total amount of "new" water entering the mine.

6.2.1.9 Best Practice 9: Hydrogeological Models

Maintain a well compiled and documented hydrogeological model to provide insight into potential water related impacts on the mining area and the surrounding catchment which can aid in developing mitigation procedures. A hydrogeological model will also inform the mine regarding plume migration and assist in arresting such plume. The model is handy in evaluating how and where boreholes can be drilled to intercept groundwater prior to it being contaminated by a tailings facility or a mining operation.

6.2.1.10 Best Practice 10: Awareness and Knowledge Dissemination

Awareness and knowledge dissemination can be a surprising way to help reduce water usage. By informing the mine employees and communities on water saving / reduction efforts that can be practiced, a mine can reduce their potable water usage by a large amount.

6.2.2 Specific Case Studies

6.2.2.1 Case Study 1: Mine A

Mine A is a South African Gold Mine. Each operation implements an Environmental Management System (EMS), through which it assesses, manages, monitors and reports on water use and the quality of any discharges. During 2016, the company spent a total of US$16m on water management and projects. Water withdrawal across the Group decreased to 30,321 Mℓ (2015: 35,247 Mℓ), and, amid stable Group gold

production, water withdrawal per ounce produced was down from 15.77 kℓ in 2015 to 13.67 kℓ in 2016. Total water recycled or reused remained steady at 44,274 Mℓ (2015: 43,120 Mℓ).
The EMS system implemented involves:

- Measuring and reporting on water management performance
- Integrating water management into mine planning
- Complying with regulatory requirements and, where feasible, going beyond compliance requirements
- Leaving an enduring, positive legacy that extends beyond mine closure

New water balance software was implemented at the Mine with links to appropriate water management plans. The water balance is an integrated surface and underground water balance. During 2016 the Mine completed Phase 1 of its post-closure water management plan (PCWMP), which assessed risks for mines that are hydraulically connected to it.

Clean and dirty water run-off is being adequately separated. Dirty water is captured in solution trenches and diverted to the Return Water dam (RWD). The water enters a silt trap prior to entering the RWD.

During 2016, South Africa found itself in a drought cycle that was one of the worst in 40 years, though good rains have fallen in early 2017. The drought meant that the three (3) reverse osmosis (RO) plants that were installed at the mine over the past two years to treat process water and reduce the intake of municipal water could not be operated for much of the year. Currently, only one of the three RO plants is operational. Three RO plants have been installed underground to supply drinking water.
A previous water balance on the site predicted that the Raw Water Dam will overflow. This resulted in the Mine exploring other alternatives to prevent this from occurring. One of these alternatives was to use reverse osmosis to produce water to potable and irrigation standards. The mine is currently utilising one of the three Reverse Osmosis (RO) plants. The plants are installed underground and have an estimated recovery of 73%.

The implementation of water recycling and conservation practices has become critical at the mine. Water awareness initiatives were introduced to encourage a reduction in water consumption. In addition, no water is discharged from the mine, other than treated sewage effluent, as authorised.

6.2.2.2 Best Practice Case Study 2: Mine B

Mine B operates various underground coal mines. Each operation has three or more shafts at different locations from each other. Mine B only daylights the coal at one of the three shafts thereby drastically reducing the dirty footprint and preventing further contamination of storm water from the site.

6.2.2.3 *Best Practice Case Study 3: Mine C*

Mine C is a sand mining operation that has been extracting heavy mineral sands from the dunes of the northern Kwa-Zulu-Natal since 1976. The strategic water management plan was implemented for the following reasons;

- The Mine is in a water-stricken catchment;
- The area surrounding the mine has valuable native ecosystems-which are sensitive to mine water discharge;
- The average annual rainfall is almost half of the global average; and
- The mine is dependent on water. In the absence of water, the operations will have to cease.

The aim of this initiative is to manage every aspect that is related to water on the site. Currently the site is operated as a closed water system management loop. The mine does not discharge any water to the environment.

- The Mine has implemented the following optimisation strategies;
- To maximise the availability of water during the drought period, the mine has raised the weir/dam wall of the lake. This will ensure that enough water is conserved and available when required.
- Underwater excavation/dredging is the mining method used. The dredges extract mineral concentrate from the mining ponds. There are four mining ponds that are currently being utilised. Abstraction occurs from the raw water supplies and are used in the smelter for quenching and processing. The process water discharged from the smelter is directed to settling ponds that surround the operations. The water from these settling ponds are recycled back to the process several times before being discharged into the mining ponds. The water discharged to the mining ponds are used to float the dredgers.
- The Mine has also optimised their tailings water treatment plant. This would assist in improving the efficiency of the plant by converting the water recovered from the tailings.
- The Mine has also evaluated strategies to modify their circuits to further reduce raw water usage.
- The Mine has looked at strategies involving their tailings stacking. They have implemented dewatering of their tailings to reduce water losses from the tailings.
- The Mine has changed pumps to improve flows

Currently the Mine is managing their water by performing an analysis on their water balance. This would assist the employees and the mine to understand which of the innovations above have been effective or where the mine can improve their water saving techniques.

6.3 INTERNATIONAL CASE STUDIES

6.3.1 Recycling of process water – Rio Tinto in Argyole diamond mine, North West Australia

Rio Tinto's Argyle Diamond mine in North-West Australia – the world's largest single producer of diamonds – is located in arid conditions reaching 40 degrees heat. The only sources of water are from two dams and Lake Argyle. In 2005 the reported water usage was 3500 MGD from the lakes. By the year 2009 they had reduced this amount to 300 MGD (almost a 95% reduction of water). This was accomplished by capturing and recycling water used within the process plant, which is the biggest user of water. Other best practices that were implemented by the mines was capturing seepage from tailings and reusing this within the process. Dewatering of the underground mines and from the surface pit operations were collected and stored in two dams. This stored water is used for drinking and other supportive operational uses. This is a common practice in mines within South Africa today.

6.3.2 Saltwater use within processing plant – Minera Esperanza's Copper and Gold mine operation in Chile

The Minera Esperanza's copper and gold mining operation is located in a water scarce region of Chile. The mine requires approximately 20 m^3 of water a year to operate. To meet these demands the mines processing plant has been designed to use untreated sea water during operations. Some of the design considerations include designing a pipe network to transport seawater which is 145 km from the Pacific coastline to the mine site.

The company has facilities at the port to assist in the conveyance of the seawater to the plant. The seawater pipeline passes through four pump stations before reaching the concentrator plant. From the plant statistics almost 8% of the water is desalinated for human use and cooling and concentrate washing.

This initiative reduces the reliance on water resources, however it is known to have its challenges and is a very energy intensive process.

6.3.3 Anglo Innovations

Anglo mining has taken many initiatives to reduce their water demand on their mining sites all over the world. Many of these initiatives include improving or optimising flow control within areas surrounding the beneficiation plant.

6.3.3.1 Evaporation, Drayton Mine, Queensland Australia

Many mining operations store water in dams to ensure a reliable water supply and to enable efficient recycling of water. Evaporation losses from these dams constitute almost 10-25% of the total water lost within a mine. This water costs amounts to a total of approximately $200 USD. The following section identifies some techniques that mines have adapted to reduce evaporation within the mines.

At the Drayton Mine in Queensland Australia new technology developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) has been installed. This new technology consists of floating buoys that calculates the relationship between local meteorological conditions and actual evaporation (over 3-6 months). This results in more accurate evaporation site data. This information would provide a better understanding of the water balance at the mine site and can focus on improving the efficiency efforts in certain areas where the evaporation is the greatest.

6.3.3.2 Dry tailings disposal

Water sent to tailings disposal often represents the largest water loss at a mine. A tailings facility consists of the fine particles from mining. These fine particle slurries are difficult to dewater and the current dry disposal methods have high capital and operating costs. An alternative approach involves combining course particle flotation to concentrate the mineral. Dry stacking has also become a phenomenal concept. Dry stacking technologies has been used to dewater residual waste and producing dry stackable tailings. It works on the principal of allowing particles to float at sizes that are two/three times larger than normal making it easier to extract water from the process, leaving behind a waste stream that is dry and stackable. These initiatives are low cost methods that will minimize the amount of water sent to the tailings facility.

6.3.3.3 Dry separation

In addition to dry processing innovative methods for dry separation are being explored. Dry separation involves finding innovative methods for dry comminution (the crushing and grinding, usually sequentially, of ore to the required particle size. More targeted comminution creates a pre-concentrate of the ore, rejecting and dewatering waste far earlier in the process. Early estimates indicate the potential for a 30-40% reduction in water used per unit of mineral production, as well as the other benefits including increased production.

6.3.3.4 Non-aqueous processing

In parallel to the dry separation technologies, laboratory testing of a non-aqueous processing technique is being conducted. This technique uses a bespoke polymer instead of water to separate the valuable ore from the remaining waste rock particles.

6.3.4 West Africa – Gold Fields Tarkwa Mine

6.3.4.1 Water Balance

Tarkwa achieved an 11% reduction in water discharged due to higher levels of water recycling and reuse and the improved water quality (as a result of rain-fed rinsing) discharged from the South heap leach facility.

6.3.4.2 Water Treatment and Monitoring

Tarkwa's North and South heap leach facilities were closed in 2014. A decommissioning plan was submitted to Ghana's Environmental Protection Agency (EPA) and their comments have been addressed which included some test work. During this method such as slope stabilisation, by planting grass to reduce runoff from the heap.

Water recycled on the South heap leach pads is now being discharged directly to the environment after test results showed that the water quality met the effluent quality guidelines. Excess water from the North heap leach is being treated at the refurbished North Reverse-Osmosis (RO) plant before being discharged and a clarifier is being installed at the North heaps to increase the volume of water to feed the treatment plant.

The operation of the RO plant, which was established, produces concentrated brine, which is being temporarily stored on site in a dedicated pond. Tarkwa has been investigating a number of options to achieve the permanent elimination of brine and employed two consulting firms to carry out pilot test work on the treatment of brine through biological, passive, or any other acceptable treatment option. Tarkwa has also been examining brine treatment through plant absorption on a 20-hectare test plot of rubber trees at the North and South heap leach pads. Irrigation of the plantation at the South heap leach helped in improving the quality, making room for discharge without treatment. Irrigation at the North heap leach, where brine concentrations are higher, is continuing and is being monitored to determine the success of the initiative.

CHAPTER 7: CONCLUSIONS & RECOMMENDATIONS

7.1 GENERAL

The success of WC/WDM initiatives and the improvement of water efficiencies within a mine site requires not only adjustments to optimising water uses but also avoiding wastage of water, water loss and incorrect usage and a reduced reliance on new water. While at its core water demand management remains a technical exercise, a paradigm shift in mindset is required at a practice and operational level that inadvertently translates into reduced water consumption through improved management or demand for water. Changing behaviour and perceptions that are focused on a broad range of interventions that aim to create a culture of efficiency and enhance the value of water in the mind of the end-user is pivotal to ensure the principles of WC/WDM are realised.

While it makes business sense to do so, it is also the right thing to do, especially in South Africa, where water demand continues to increase against a backdrop of a limited water resource. As water is scarce, mine water consumption can severely impact local supplies. Reducing water consumption is a key requirement in moving toward a more sustainable mining industry.

A WC/WDM approach on site must ensure that it:

- Is incorporated in the mine water management plan/strategy;
- Educates mine personnel and management on the water management strategy and actions;
- Improves the mine water system design;
- Implements efficiencies of water use, where more is done with the same volume of water;
- Limits and stops water losses;
- Reduces wastage;
- Practices re-use and re-cycling of water;
- Ensures properly operated mine water management systems (process, contact and freshwater);
- Eliminates/minimizes unwanted mine water discharges;
- Includes effective metering;
- Has a site wide water balance in place;
- Considers cost benefit analysis of the of water use actions and measures applied, in terms of the site wide mine water balance and as well as the catchment balance; and
- Creates awareness of water conservation.

A holistic integrated approach to WC/WDM:

- Includes the understanding of principles, scope and the potential of WC/WDM interventions as a strategic action;

- Driven by policy at a board level;
- Applied as management tool;
- Water and perceived value;
- Addresses Perceptions – Changes perceptions that WC/WDM strategies are implemented as punitive measures;
- Drives the will of senior management;
- Understands the Economics of investing in WC/WDM;
- Incorporates proper planning;
- Integrates between operations on a mine;
- Ring-fences water and water use;
- Considers financial investment in infrastructure;
- Adopts best practices and technologies;
- Incorporates appropriate WC/WDM planning tools and guidelines;
- Evaluates demand side management – Water supply side is a last resort;
- Addresses changing attitudes and changing habits related to water use; and
- Focuses on WC/WDM awareness creation and education within the organisation and at operating mines.

7.2 KEY FINDINGS

Golder undertook the project to develop a compendium of best practices and innovations to highlight WC/WDM principles in the South African mining industry. The project undertook a desktop assessment by identifying mines for further investigation and site visit. This was done via telephonic and email questionnaires. Those mines that were identified as having the most potential and promising initiative were selected for a more detailed assessment which included site visits and gathering of data.
A literature survey was also conducted to provide more insight into what is available within South Africa and globally. The literature survey also served to provide information on comparing the water situation between South Africa and other countries as well as describing the legislative context within which these companies operate. Water saving initiatives, technologies and best practices were presented in the compendium with numerical results of the water saving project.

The key findings as a result of the project is that application of technologies and innovations within the mining industry in South Africa to conserve water and better manage the water demand is scarce. Most of the improvement in technology, if any, relates to revenue creation with a side benefit of water savings. Over the past few years this emphasis has shifted and companies are slowly realising the important impact water has on their operations and vice versa. Therefore, not many highly innovative or advances in technologies have been implemented successfully within the South African mining industry. A lot of the innovations and technology changes have occurred very recently without sufficient information and data to prove the success of the technologies. However, it must be noted that there is a definite shift in awareness with more and more initiatives and best practices being considered and implemented.

However, various best practices and innovations are presented in this report to provide a Compendium to the mining industry. This document will ensure better knowledge dissemination and sharing of innovations and ideas to the mining industry. The South African mining industry now possesses an arsenal of potential ideas that can be implemented at their operational sites to assist in the reduction of water demand and conservation of water.

7.3 CREATION OF NEW KNOWLEDGE

This project has not necessarily created new knowledge but has increased the awareness of the relatively new knowledge or concept of WC/WDM and how to implement this. The concept of demand management and impacts of water use on the catchment has been constantly emphasised throughout this project.
Not necessarily new knowledge but more advances with regards to technology changes on old concepts were brought to the fore, e.g. x-ray sorting, filtration technology, water treatment and waste management.

7.4 GAPS AND FURTHER STUDIES REQUIRED

As part of the project various knowledge dissemination activities were conducted, however, it has been identified that awareness regarding the concept of WC/WDM and the know-how to implement the WC/WDM principle is lacking to some extent in the industry. The following gaps have been identified which were not addressed as part of this project:

- Additional awareness and knowledge dissemination is required.
- The report did not cover the impact of human behaviour on WC/WDM. Knowledge, understanding and practicing good water management can impact water use to a large extent. The actual quantification of this will need to be done.

The following new research is recommended to ensure any technology gaps are bridged:

- The principle behind WC/WDM is to reduce the use of new water from the catchment and re-use and recycle as much water as possible within the operations. This process in itself may result in the accumulation / concentration of waste within the system. More research must be conducted with regards to the waste management concepts. Specific focus should be on:
    a. Beneficial re-use of brine by encapsulation and or paste technology.
    b. More research of freeze crystallisation and the downstream use of brine.
    c. More research of FGX technology.
- The innovations that have been described in the report include:
    a. The Tomra x-ray sorting process.
    b. The Enprotech filtration technology.

c. Possibility of using mine affected gypsiferous water for irrigation.

d. Passive water treatment technologies.

- It is recommended to conduct further research of the above by:

  a. Piloting these technologies across different commodities, geographical locations and catchments to determine the efficacy of the technology. Data needs to be gathered and stored, assessed and analysed to present to the mining industry to allow for the industry to be able to understand the quantification of the benefits to their specific application.

  b. Research at coal and other mines to determine whether using gypsiferous water for irrigation is possible at these mines.

  c. More pilot studies at lab and industrial scale to gather more data regarding passive water treatment technologies. Most mines will end up having a long-term water quality liability which results in active water treatment being costly and impractical. There is currently no proven passive water treatment application that be implemented.

- The Standardised Water Accounting Framework (SWAF) online system requires funding and motivation to be implemented. This system will allow for the collection of data from the mining industry to be able to provide data to the industry with regards to the industry benchmarks and catchment water balance.

- Improvement in enforcement and adequate knowledge sharing and training is required to ensure that water balances and WC/WDM is conducted in a manner that ensures the highest confidence with regards to the results. This is imperative since this will feed into providing a better understanding of catchment water availability and catchment water balance.

- Golder attempted to reach out to all possible mining companies that showed potential of WC/WDM innovation and effort, however, due to project time and budget restrictions it was not possible to reach out to all. Golder recommends that this project be extended to include a Phase 2 to bridge these gaps. Some of these gaps include:

  a. Include sand mining operation, e.g. Richards Bay Minerals,

  b. Including diamond and platinum mining operations;

  c. Adding specific operational data from the EWRP and other major water treatment facilities;

  d. Inclusion of current piloting and data from gypsiferous irrigation project;

  e. etc.

- To provide more assistance to mining companies within South Africa, it will be beneficial to include global initiatives and providing data showing the success of these global initiatives. The ICMM has published such a document, however, the focus needs to shift to processing technologies where a larger demand of water is being used. Partnering with institutes like Coaltech in South Africa and the ICMM or other institutes should be considered.

- The impact of changes in behaviour of the employee to water reduction and savings is well known but not well documented. Due to time and budget constraints on this project, this aspect could not be investigated fully. Further research is required on this topic.

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APPENDIX 1 – REGULATORY FRAMEWORK FOR WATER CONSERVATION AND WATER DEMAND MANAGEMENT

INTRODUCTION

Given that water is a scarce and finite resource in South Africa and many other countries, an appropriate regulatory framework is critical to the State's ability to regulate, control, and allocate water resources sustainably. While it is important that the regulatory framework lays down clear and comprehensive rules, it should still be sufficiently flexible in order to accommodate future challenges and changes in priorities and perspectives (Salman and Bradlow, 2006). The following section presents an overview of the regulatory frameworks governing WC/WDM in South Africa and internationally.

SOUTH AFRICAN CONTEXT

A high-level overview of current legislation, policies, plans and programmes in South Africa that both promotes and enforces WC/WDM[10] is presented below. Water usage in the South African mining industry is predominantly governed by the following legislation:

- The Constitution of 1996;
- The National Water Act of 1998 (NWA);
- The Water Services Act of 1997 (WSA);
- National Environmental Management Act of 1998 (NEMA); and
- Minerals and Petroleum Resources Development Act of 2002 (MPRD).

The main purpose of the NWA is to ensure the water resources of South Africa are protected, used, developed, conserved, managed and controlled in accordance with the nation's best interests. The promotion of WC/WDM supports the underlying principles and aims of the NWA.

The Constitution

The Constitution (Act No. 108 of 1996) of South Africa laid the foundation for a democratic society for the people of South Africa. This foundation provides the basic principles on which all other policies and legislation are based.

The environmental rights of the people of South Africa are specified in Section 24 of the Constitution, which guarantees everyone the right to an environment that is not harmful to their health or well-being and to have the environment protected for the benefit of present and future generations, through reasonable legislation and other measures that promote *conservation* amongst others. This section

[10] This section is an updated abstract from an earlier report prepared by Golder Associates Africa (Pty) Ltd for the CoM and DWAF entitled "*Literature Review for the Setting of Targets for Water Conservation and Water Demand Management in the Mining Sector*" (Report No. 12614165-11686-1)

therefore includes the most significant aspect related to water conservation, which emphasises the need for WCWDM to play a central role in the manner in which water resources are used and managed.

National Water Act (Act 36 of 1998)

The fundamental principles of the National Water Act (Act No. 36, 1998), (NWA) are sustainability and equity. These serve as central guiding principles in the protection, use, development, conservation, control and management of water resources. One of the purposes of the NWA is the promotion of efficient, sustainable and beneficial use of water in the public interest, whilst providing for growing demand of water use. The NWA also requires the development of strategies to facilitate the proper management of water resources. It makes provision for water management strategies to be developed on the following three tiers:

- National Water Resource Strategy, providing the overarching framework as to the management of the water resources across South Africa;
- Catchment management strategies relating to the management of water resources within a water management area; and
- Strategies related to water resources management *viz.* the National WC/WDM strategy, Water Pricing Strategy, amongst others.

> **Conservation**:
> In relation to a water resource means the efficient use and saving of water, achieved through measures such as water saving devices, water-efficient processes, water demand management and water rationing.
> (Section 1(v), NWA, Act No. 36 of 1998)

Section 6 (1)(h) of the NWA (Act No. 36 of 1998) requires that the contents of the NWRS must: “set out the principles relating to water conservation and water demand management.”

The NWA therefore provides an enabling mechanism for WC/WDM measures to developed and implemented, thereby forming an integral component of how water resources are protected, controlled, used, developed and managed. In this regard, provisions are included in various chapters of the NWA. These include, inter alia, water management strategies (Chapter 2), protection of water resources (Chapter 3), water use (Chapter 4), financial provisions (Chapter 5) and catchment management agencies (Chapter 7).

Provisions and requirements of the NWA (Act No. 36 of 1998) that directly or indirectly relate to water conservation, include amongst others:

- Resource protection measures;
- Conditions for water use in water use authorisations (e.g. licences, general authorisations);
- Water pricing as an incentive for efficient water use;
- Management of land-based activities via stream flow reduction or controlled activities; and
- Control of alien invasive species.

National Water Resource Strategy (NWRS)
The NWRS provides a framework within which integrated water resource management will be achieved in South Africa. It provides a legally binding framework within which the water resources of South Africa are managed in the future and identifies opportunities for social and economic development. It outlines the goals and objectives of water resources management for the country and provides policies, plans, guidelines and strategies to achieve these goals. It also provides quantitative information about present and future availability of and requirements for water in each of the 9 Water Management Areas (WMAs) and proposes interventions by which these may be reconciled. Two editions of the NWRS have been published to date.

The purpose of the second edition of the National Water Resource Strategy (NWRS) *is to ensure that national water resources are managed towards achieving South Africa's growth, development and socio-economic priorities in an equitable and sustainable manner over the next five to 10 years* (NWRS, June 2013, Second Edition).

The NWRS is the legal instrument for implementing or operationalising the NWA. It is thus binding on all authorities and institutions implementing the Act and is the primary mechanism to manage water across all sectors towards achieving national government's development objectives.

The concept of WC/WDM is included in the National Water Resource Strategy (NWRS) as one of the key focus areas and is included in the DWS Water Sector Priority Focus Area for 2013-2018 as shown below. WC/WDM is also a key component of the DWS Reconciliation Strategies for major water supply systems.

Figure 63: The NWRS Water Sector priority focus areas for 2013-2018

While there is a legislative requirement under the NWA to develop a NWRS, there is also a need to respond to new strategic drivers, challenges and priorities. The second edition of the Strategy (NWRS2) outlines the key challenges, constraints and opportunities in water resource management and proposes new approaches to be adopted in ensuring effective challenges, constraints and opportunities. The NWRS2 specifically addresses WC/WDM in Chapter 7 on strategies for water resources management.

Water Conservation:
Is the minimisation of loss or waste, the care and protection of water resources and the efficient use of water.

Water Demand Management
Is the adaptation and implementation of a strategy or a programme by a by a water institution or consumer to influence the water demand and usage of water in order to meet any of the following objectives: economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services and political acceptability.
(DWS, NWRS2, 2013)

National Water Conservation and Water Demand Management Strategy
The National Water Conservation and Water Demand Management Strategy (WC/WDM) published by the then DWA in August 2004, serves as the guiding framework for the implementation of WC/WDM measures in the management of water resources and water services provision in South Africa. The strategy outlines the measures and interventions aimed at encouraging and supporting water institutions and water users to increase the efficiency of their water use and reduce their demand for water. The NWC/WDM Strategy is supported by sectorial strategies for three identified sectors, *viz*. water services, agriculture and industry, mining and power generation. The core objectives of these strategies are to create a WC/WDM culture within all water management and water services institutions defined in the NWA and WSA and among water users.

According to the strategy, the most promising opportunities for WC/WDM in the mining sector will lie in the following:

- Implementation of new technology whereby water use is limited/reduced;
- Reuse of water where possible within the boundaries of the operation;
- Reuse of water between operations across boundaries; and
- Implementation of pollution abatement technologies that will further alleviate water demand.

These opportunities will lead to reduced operating cost, the sustainable use of resources, the environmental protection of water sources, the meeting of international standards and it will reduce the overall impact on the regional water resources. The strategy clearly defines its objectives as summarised in Table 24:

Table 24: National WC/WDM strategy framework objectives

Objective	Description of Objective
Objective 1	To facilitate and ensure the role of WC/WDM in achieving sustainable, efficient and affordable management of water resources and water services
Objective 2	To contribute to the protection of the environment, ecology and water resources
Objective 3	To create a culture of WC/WDM within all water management and water services institutions

Objective	Description of Objective
Objective 4	To create a culture of WC/WDM for all consumers and users
Objective 5	To support water management and water services institutions to implement WC/WDM
Objective 6	To promote the allocation of adequate capacity and resources by water institutions for WC/WDM
Objective 7	To enable water management and water services institutions to adopt integrated planning
Objective 8	To promote international co-operation and participate with other Southern African countries, particularly basin-sharing countries, in developing joint WC/WDM strategies.

The key strategic outputs required for the Industry Mining and Power Generation Sectors which links the NWRS framework of objectives are:

Table 25: Key strategic outputs required for the Industry Mining and Power Generation Sectors

Output	Description of output	Link to objectives
1	Carry out ongoing water audit and water balance	3, 4, and 5
2	Benchmark, as far as possible and practical, water use for various processes and industries	3 and 4
3	Performance monitoring against benchmarks	3 and 4
4	Implement water conservation programmes	2, 3 and 4
5	Marketing and publicising water conservation	3 and 4

The WC/WDM strategic actions according to the NWRS Chapter 7 are therefore to:

- Ensure that relevant, practical interventions are implemented by all sectors.
- Implement water allocation and water use authorisation that entrenches WC/WDM.
- Strengthen compliance monitoring and enforcement.
- Implement water resource infrastructure development in the context of WC/WDM.
- Setting of targets; and
- Develop an institutional capacity within the DWS to manage and regulate WC/WDM effectively.

The strategy also addresses the constraints affecting successful implementation of WC/WDM in the industry, as well as the opportunities expected to be the driving factors in this regard. The general constraints are:

- **Financial Constraints:** Capital investment is not always readily available and the cost of such a project may not always be recovered.
- **Institutional Constraints:** This is mainly due to a lack of co-ordination between the role-players in the water supply chain during the planning phase of such projects.
- **Limited Awareness:** Limited awareness of the need for WC/WDM and the effects of not implementing such measures are often found in the Mining and Industrial sector.
- **Technical Constraints:** The lack of application specific tools and guidelines stifle the implementation of adequate WC/WDM implication.

Generic Water Conservation/Water Demand Management (WC/WDM) Framework Guidelines for the Mining Sector

The aim of the development of the Generic WC/WDM Framework Guidelines for the Mining Sector was to identify and assess the opportunities and constraints in implementing comprehensive WC/WDM measures in the mining industry. In developing the framework, a detailed situation assessment was undertaken. The key findings of this assessment include the following:

- Average water usage (where figures are known) is about 0.2 m^3 per ton for the coal mines, 0.4 m^3 per tonne for gold mines, 0.7 m^3 per tonne for platinum mines, 0.86 m^3 per tonne for copper and about 0.9 m^3 per tonne for diamond mines. It must be noted, however, that these data were gathered prior to 2005;
- The mines generally have effluent / storm water management systems that separate clean and dirty water as well as a system of dams for dirty water management;
- The development of water management structures varies between mines and areas; and
- WC/WDM initiatives centre on minimising the dirty water in the system, developing more efficient means of managing this dirty water and replacing raw water use with recycled water.

Benchmarks for Water Conservation / Water Demand Management in the Mining Sector: Indicators and Commodity-based Water Use Efficiency Benchmarks

The purpose of the guideline was to present appropriate benchmarks for WC/WDM in the mining sector. It defines appropriate Water Use Efficiency (WUE) indicators for the mining sector for the different commodity groups (coal, gold, platinum and other), based on the data collected during site visits to various mines. National WUE benchmarks (not targets as originally intended) were identified based on the current WUE indicators for the top three performing mines within each commodity group (with the top three mines being selected based on an objective assessment of the survey results for the mines with regard to a wide range of water management indices). An implementation methodology that provides technical guidance to mines as to how they should develop a mine-specific WC/WDM plan that includes mine-specific WUE targets that are designed to optimise the mine's WUE was also developed as described below.

Guideline for the Development and Implementation of Water Conservation / Water Demand Management Plans for the Mining Sector

The purpose of the guideline is to support the mining sector in developing and implementing WC/WDM management plans. It starts by providing a general overview of the WC/WDM implementation framework. It then details the implementation responsibilities of the mining industry and the specific actions that DWS are required to undertake. Included in the guideline is a specification of generic WC/WDM measures, as well as a practical guide for compilation and development of a comprehensive WC/WDM plan using a case study.

INTERNATIONAL CONTEXT

Table 26 below presents an overview of the frameworks regulating WC/WDM in selected countries. These countries were selected as they are either world leaders in the production of certain commodities, such as gold, coal, platinum, diamonds, iron ore or chrome, or they experience the same challenges as South Africa in terms of water scarcity, or both Table 26 below lists the applicable legislation and policies and guidelines for each country, as well as a general comment on the strengths and weaknesses of their regulatory framework in the context of WC/WDM in the mining sector.

Table 26: Overview of the Regulatory Framework in Selected Countries[1]

Country	Legislation	Policies & Guidelines	Comments
Australia	• Australian Constitution; • Environment Protection and Biodiversity Conservation Act (1999); • Environment Protection and Biodiversity Conservation Regulations (2000).	• Leading practice sustainable development program for the mining industry – Water management (2008); • Western Australian water in mining guideline (2013).	• Australia is a Commonwealth federation comprising of six states and two self-governing territories. The Constitution sets out which competences are governed by the Federal (Commonwealth) government and which are the jurisdiction of the states. • Minerals and mining activities are generally regulated at the state level, rather than at the federal level. There are, however, some exceptions, such as the environment, where the Commonwealth has some regulatory powers which take precedence over any inconsistent state legislation. • Water use efficiency is encouraged in "Operational policy no.1.02 – Policy on water conservation/efficiency plans: achieving water use efficiency gains through water licensing". • Australia has adopted 'leading-practice water management' approach to water management. Leading practice involves developing clear water management objectives for a site, strategies to achieve those

Country	Legislation	Policies & Guidelines	Comments
			objectives, and the set-up of an adaptive management framework that allows the proponent to assess and, where necessary, adjust site management. It is therefore as much about a company's approach to managing its water resources, as it is about a fixed set of practices or a particular technology. With this approach, as new challenges emerge, it is critical that companies are flexible and innovative in developing water efficient solutions to match their site-specific requirements. Many mining companies currently demonstrate **leading practice management.**
Botswana	• Water Act (1968).	• Botswana National Water Policy (2012); • Botswana National Water Master Plan (1991); • Botswana Integrated Water Resources Management & Water Efficiency Plan (2013).	• Recent policies and plans reflect a shift in water management from a focus on supply and large water development schemes to the prioritisation of WDM; • Water policy supports WC/WDM to promote environmental sustainability, economic efficiency and social equity. Includes a number of strategies to promote WC/WDM; • Water master plan promotes alternative technologies for water management and conservation.
Canada	• Water Act (1985); • Canadian Environmental Protection Act (2012).	•	• Water Act focuses on regulating the conservation, development, and utilisation of water resources, as well as water quality management; • Water quantity and availability is not a priority as Canada is not generally a water scarce country.
China	• Constitution (1999); • Water Law (2002); • Environmental Protection Law (1989); • Water and Soil Conservation Law (1991); • Water Pollution Law (1996).	•	• Legislation promotes the development, sustainable use, management, and protection of the water resources in a way that contributes to economic and social development in China (Salman and Bradlow, 2006); • Emphasis on using water for multiple purposes and on obtaining maximum benefits from the water used; • Article 21 of the Water Law stipulates priorities in water uses, with the highest priority assigned to domestic needs, followed by

Country	Legislation	Policies & Guidelines	Comments
			agriculture, industry, environment, and lastly navigation; • Article 8 of the Water Law requires the various levels of government to develop and promote water-saving technology and industries; • Strong focus on the regulation of water uses (i.e. maximise economic and social welfare) and the protection of water resources (i.e. water quality); • WC/WDM implied through references to sustainable use of water resources.
India	• Draft National Water Framework Bill (2016); • National Water Policy (2012).	•	• The current legislation, policies and guidelines are generally focussed on supply-side issues, in particular water provision, security of supply and water quality; • Section 6 of the water policy makes provision for water demand management and water use efficiency; however, these are generally high-level principles.
United States of America	• Clean Water Act (1972). • Arizona Department of Water Resources (ADWR) Water Conservation Requirements (2010) (Singh, 2010)	• Best Practices to Consider When Evaluating Water Conservation and Efficiency as an Alternative for Water Supply Expansion (2016); • Guidelines for Water Reuse (2004).	• Legislation regulating water resources and the mining sector generally focused on water quality management; • Best practices, while not specific to mining advocate supply-side and demand-side accounting, water loss minimisation, metering, end use water conservation and efficiency analysis and developing a water conservation and efficiency plan; • The ADWR has developed requirements for conservation, monitoring and reporting for metal mines in the state. All mines in Arizona are required to comply with implementing specific water saving initiatives, adopting conservation measures as stipulated by the ADWR, submit a long-range water conservation plan to the ADWR at least three months prior to the start of a new operation. The ADWR stipulates specific water efficiency measures that must be reported in the long-range water conservation plan.

[1]Note that the above summary is only a broad overview of WC/WDM implementation in the selected countries, as is not a comprehensive review the regulations, or guidelines relating to water management in the mining sector.

APPENDIX 2 – MINING IN SOUTH AFRICA

INTRODUCTION

South Africa is well endowed with a considerable mineral resource base which includes coal, iron ore, diamonds, mineral sands, copper, gold, platinum and oil and gas, which have given rise to significant mining activities in many regions of the country. Mining in South Africa has been the main driving force behind the history and development of Africa's most advanced economy.

South Africa's mineral wealth is found in diverse geological formations, some of which are unique and extensive by world standards. Some of the country's minerals include:

- Gold – the unique and wide-spread Witwatersrand Basin yields some 94% of South Africa's gold output.
- Diamonds (in kimberlites, alluvial and marine) – the country is among the world's top producers.
- Titanium – heavy mineral-sand occurrences containing titanium minerals are found along the coasts.
- Manganese – significant reserves of manganese are found in the sedimentary rocks of the Transvaal Supergroup.
- Platinum Group Metals and chrome – these minerals occur in the Bushveld Complex in Mpumalanga, Limpopo and the North West. More than half of the global reserves of chrome and platinum are found in this deposit.
- Coal and anthracite beds occur in the Karoo Basin in Mpumalanga, KwaZulu-Natal and Limpopo.
- Copper phosphate, titanium, iron, vermiculite and zirconium are found in the Phalaborwa Igneous Complex in Limpopo.

Figure 64 presents the spread of mineral provinces and the mine projects and commodities in 2016.

Diamond and gold production may now be well down from their peaks, though South Africa is the 6th largest gold producer in the world but South Africa remains endowed with mineral riches. It is the world's largest producer of chrome, manganese, platinum, vanadium and vermiculite. It is the second largest producer of ilmenite, palladium, rutile and zirconium. It is also the world's third largest coal exporter. South Africa is also a huge producer of iron ore.

With the growth of South Africa's secondary and tertiary industries, the relative contribution of mining to South Africa's gross domestic product (GDP) has declined over the past 10 to 20 years. Nonetheless, the industry is continually adapting to changing local and international world conditions, and remains a cornerstone of the economy, making a significant contribution to economic activity, job creation and foreign exchange earnings. Mining and its related industries are critical to South Africa's socio-economic development. The potential is still huge. The sector accounts for a significant portion of the market capitalisation of the JSE and continues to act as a magnet for foreign investment in the country.

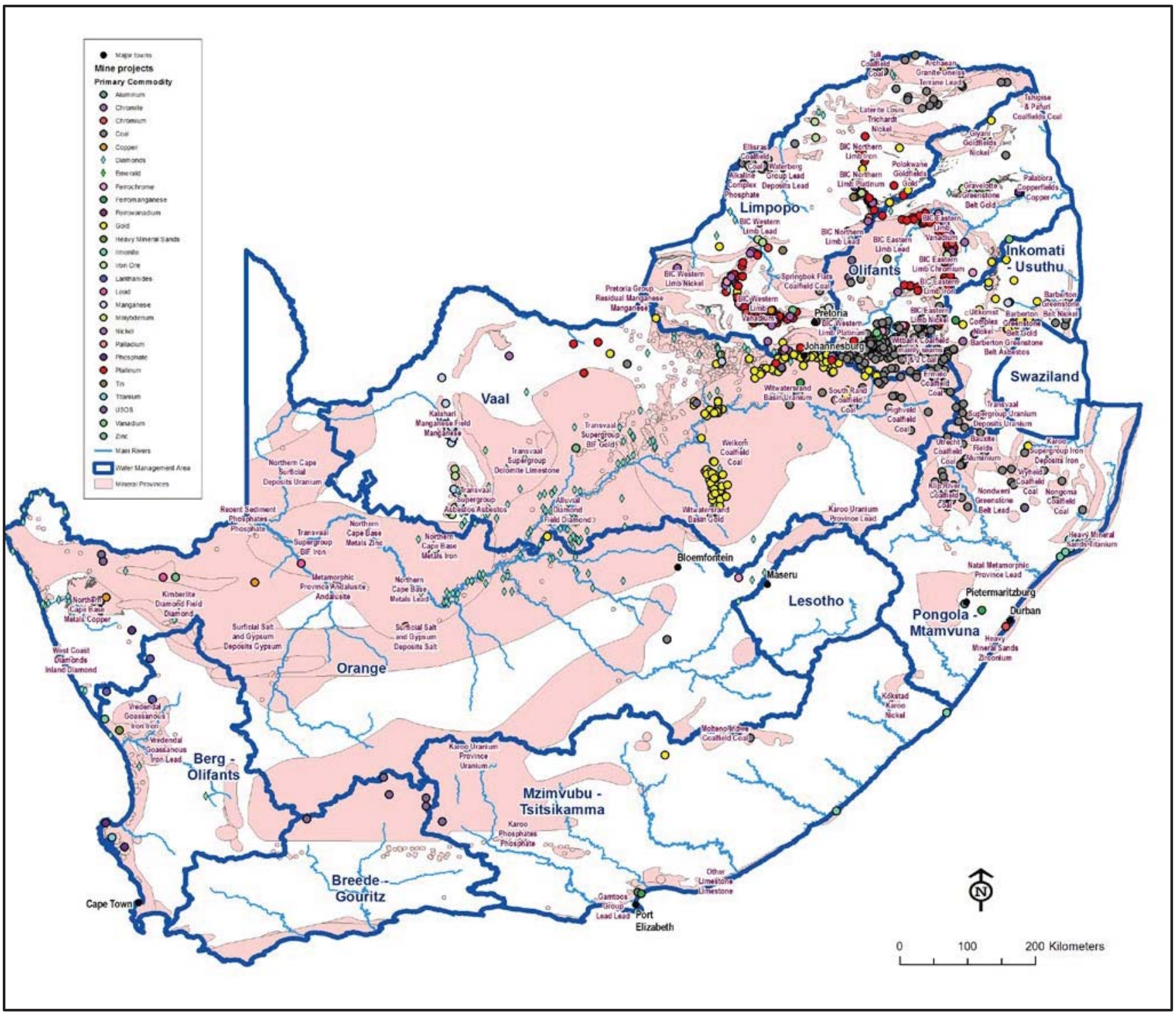

Figure 64: Mineral Provinces and mine projects (commodities) in 2016

Key mining facts from the Minerals Council, 2018 (Chamber of Mines):

- In 2017 the mining sector contributed R 335 billion or 6.8% to the gross domestic product of the country as shown in Figure 65.
- The sector employed 464 667 people in 2017 (Figure 66).
- The mining sector has, for many years, attracted valuable foreign direct investment to South Africa. It contributed to 20% of private investment in 2015.
- The mining industry contributed to 88% of metals exported.
- In addition to the people directly employed in the mining sector, it is estimated that every mining employee supports between 5 and 10 dependants; therefore, indirectly the mining industry supports approximately 4.5 dependants.

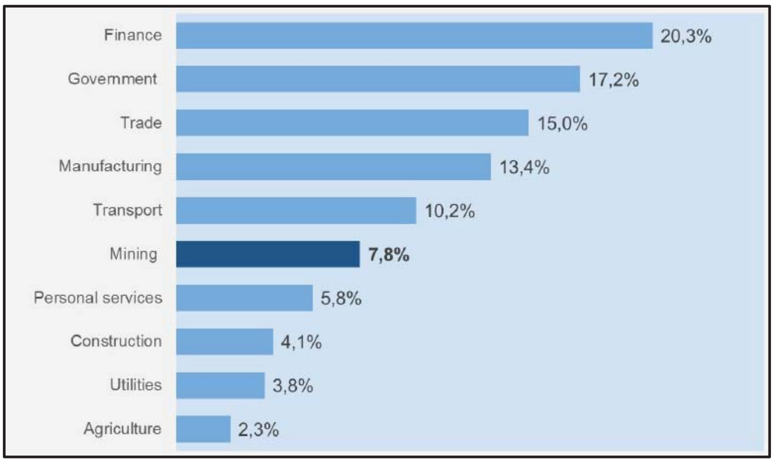

Figure 65: Contribution to economic activity in 2015 (Lehohla, 2017)

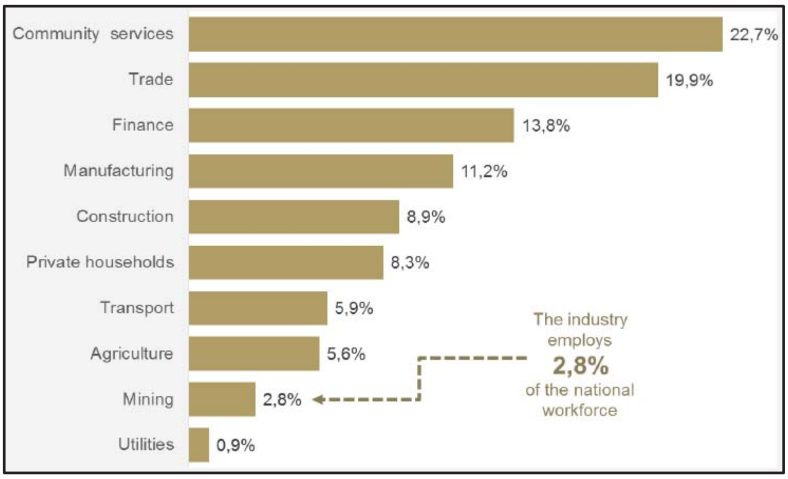

Figure 66: Contribution to the national workforce in 2015 (Lehohla, 2017)

MAJOR COMMODITIES

The major mining commodities in South Africa (Table 27) are:

- Gold
- Coal
- Platinum-group metals
- Diamonds
- Iron ore

Table 27: South Africa's production and sales in 2014 (DMR, 2016)

Commodity	Production	Local Sales		Export Sales		Total Sales	
Gold	151.6 t	8.5 t	R 3.45 b	136 t	R 59.8 b	144.6 t	R 63.3 b
PGMs	188.4 t	28.5 t	R 10.6 b	201.5 t	R 66.9 b	230.0 t	R 77.5 b
Diamonds	8.06 Mct	3.13 Mct	R 8.7 b	5.62 Mct	R 7.7 b	8.75 Mct	R 16.5 b
Coal	261 Mt	183 Mt	R 54.9 b	75 Mt	R 50.9 b	258 Mt	R 106 b
Iron ore	81 Mt	9.5 Mt	R 5.7 b	62 Mt	R 53 b	71 Mt	R 58.7 b
Chrome ore	14 Mt	10 Mt	R 7.8 b	3.7 Mt	R 5.8 b	13.7 Mt	R 13.6 b

For each of these commodities, a detailed description is provided in the sub-sections below.

Gold

In 2014, South Africa was the sixth largest producer of gold, with Canada being the largest producer (42.4% of the global production), followed by China (14.8%), Australia (8.7%), Russia (8.4%), and United States (8.4%). South Africa's contribution to global production has been declining over the years, due to lower grades, the challenges of deep-level gold mining as well as lower recovery of scrap-gold. South Africa has 28 primary gold mining operations which contributed approximately 91.7% to gold rough bullion.

As shown in Figure 67, the gold mining operations are primarily located in Gauteng, North West, Free State, Mpumalanga, and Limpopo. Also shown is the location of the major mining houses' operations. This includes AngloGold Ashanti, Harmony, Sibanye, Gold Fields, Pan African Resources and Village.

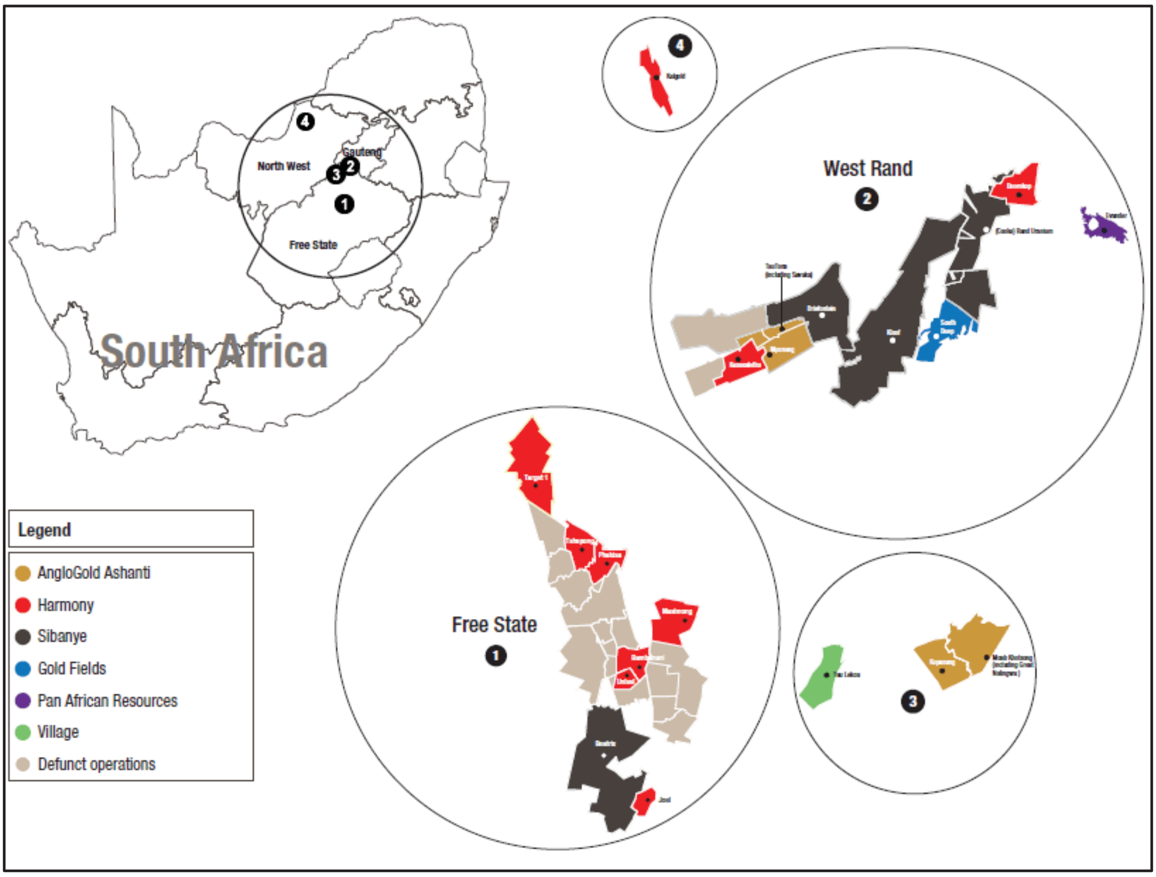

Figure 67: Location of primary gold mining operations (CoM, 2017)

Platinum-Group Metals

In 2014, South Africa was the world's largest producer of PGMs accounting for 70% of global production. Russia contributed 13.8% to global production, with Canada, United States, and Zimbabwe making up the remaining 17%.

The PGM mining operations are primarily located in the North West, Mpumalanga, and Limpopo (see Figure 68). Implats, Amplats and Lonmin jointly produce up to 80% of global PGM supplies.

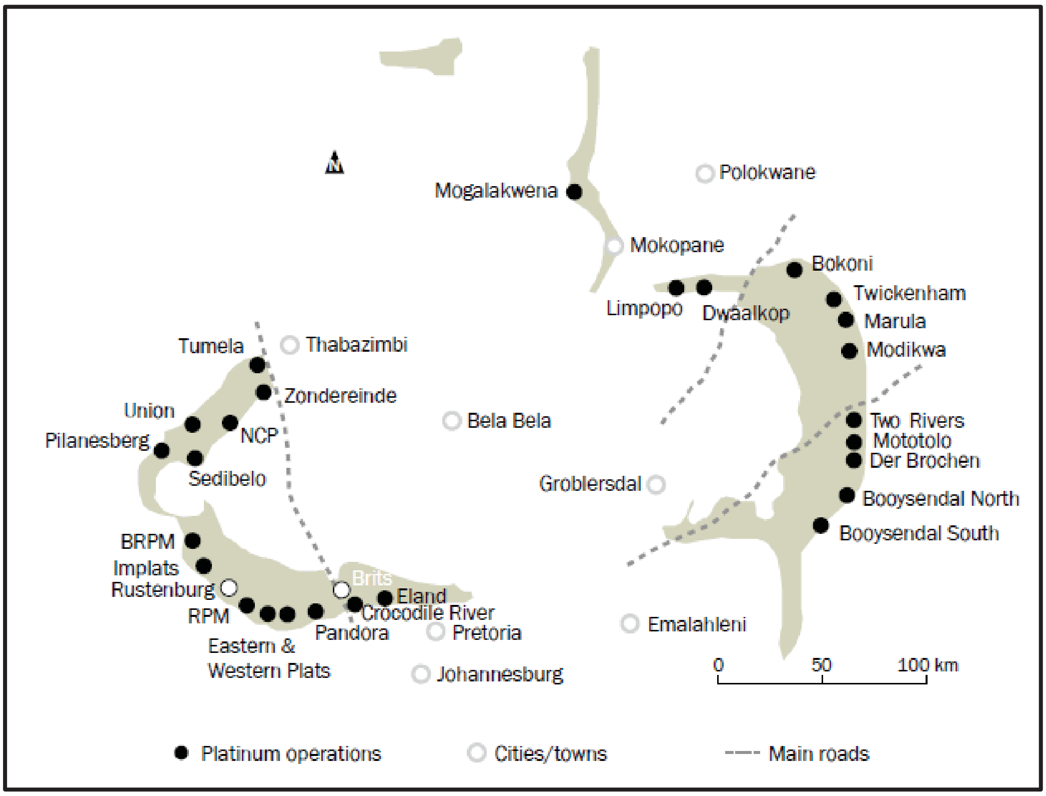

Figure 68: Location of platinum mining operations (CoM, 2017)

Diamonds

In 2014, South Africa was ranked as the seventh largest producer of Diamonds by volume, with an output of 8.1 Mct (DMR, 2016). Russia remained the largest global producer (30.7% of global production), followed by Botswana (19.8%), Democratic Republic of Congo (12.5%), Canada (9.6%), Australia (7.5%), and Angola (7.1%). Kimberlite pipe mining accounted for 96.6% of South Africa's production, with alluvial and marine diamonds making up the remaining 3.4%.

As shown in Figure 69, the diamond mining operations are generally located inland and on the west coast of South Africa. De Beers and Petra Diamonds jointly produced 96.4% of the diamonds from kimberlites, while Alexkor and Trans Hex jointly produced 90.3% of marine diamonds.

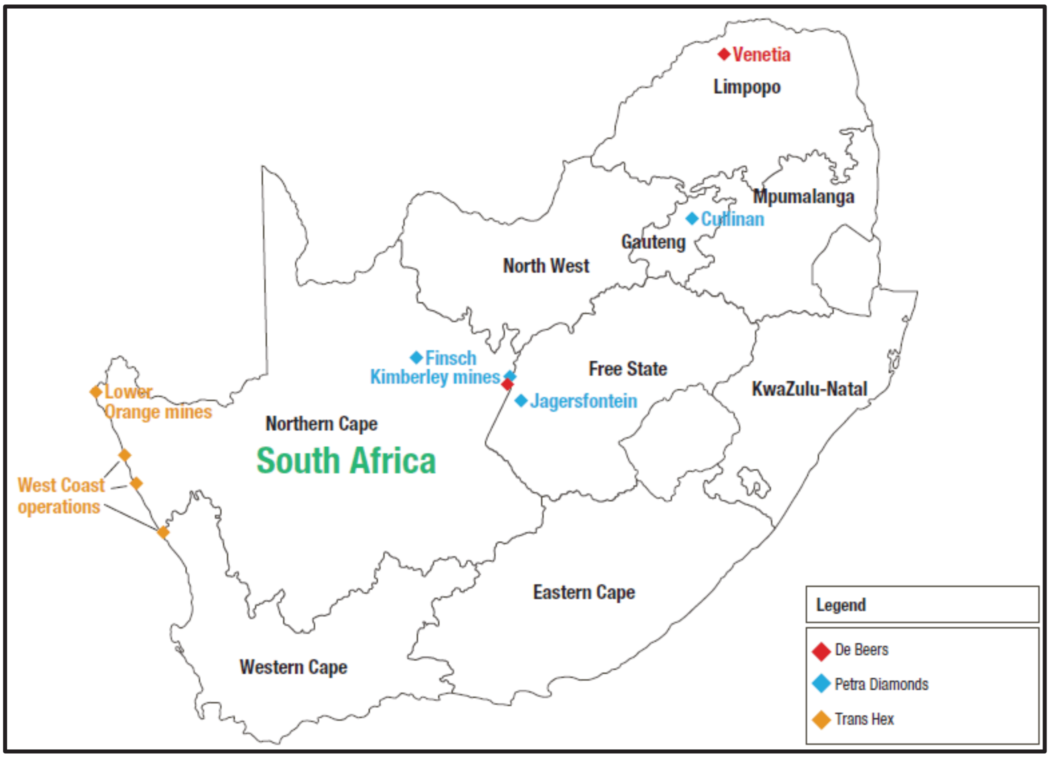

Figure 69: Location of diamond mining operations (CoM, 2017)

Coal

In 2014, South was ranked as the seventh largest producer of coal, with the 5th largest coal reserves. China was the largest producer of coal (47.4%), followed by the United States (11.1%), India (7.9%), Australia (6%), Indonesia (5.6%), and Russia (4.4%). During the same period, there were 93 coal producing mines, with open cast mining accounting for 63% of production, followed by board and pillar (34.9%), stooping (1.5%) and longwall (0.5%). Jointly, Anglo Coal, Glencore, Exxaro, SASOL and South32 accounted for 74.2% of coal production, with Exxaro Resources, Optimum Coal Holdings, Umcebo Mining and Shanduka Coal accounting for 24% of the remaining 25.6% of the coal production.

Figure 70 below shows the location of some of South Africa's major coal mining operations, which are generally located in Mpumalanga and Limpopo.

Iron Ore

In 2014, South Africa was ranked as the seventh largest producer of iron ore (2.48% of global production) (DMR, 2016). China was the largest producer (47.7%), followed by Australia (19.4%), Brazil (10%), India (4.8%), Russia (3.3%), and Ukraine (2.6%). Iron ore production in South Africa declined by 12.9% between 2013 and 2014, as some high cost producers closed down in response to the low prices.

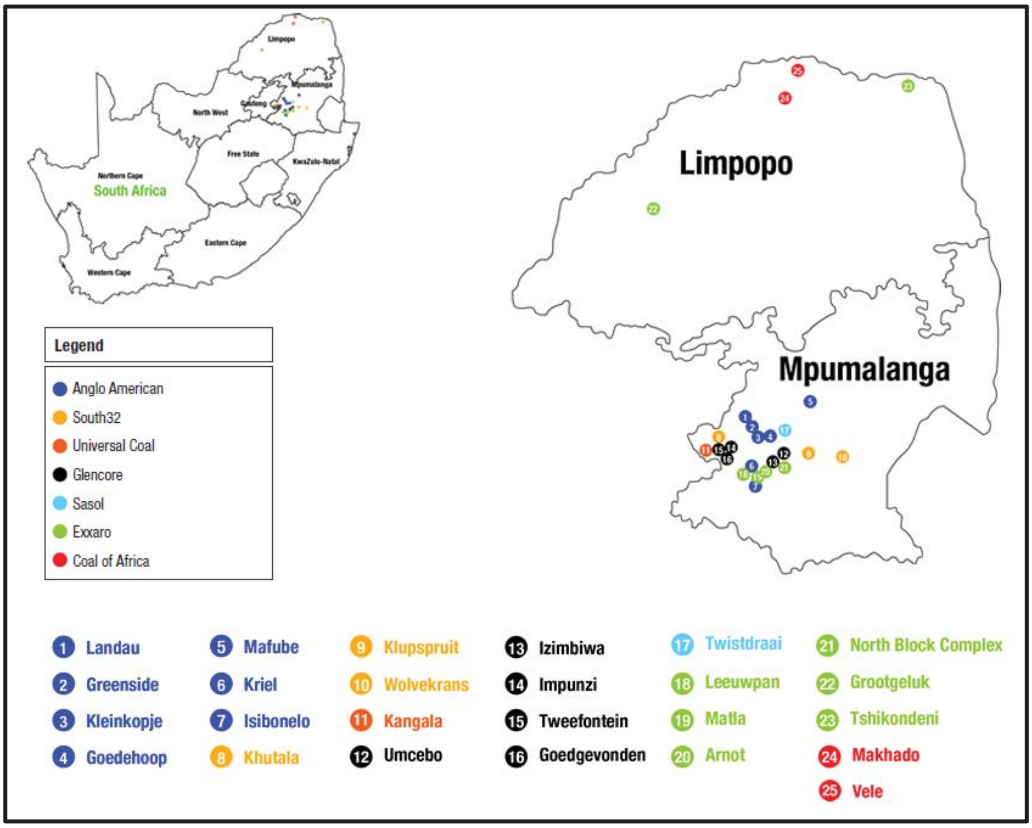

Figure 70: Location of coal mining operations (CoM, 2017)

Chrome

In 2014, South Africa was ranked as the largest producer of chrome ore (43.5% of global production), with 73.7% of the world's remaining reserves. Kazakhstan contributed 19.3% to global production, followed by India (8.3%), and Turkey (7.5%).

WATER AND THE MINING INDUSTRY

Water is vital for many mining operations and has moved from being merely an input to production to an asset. It is, however, also expensive, the source of many problems and additional major costs. It should be emphasized that a successful mining operation depends largely on the adequate consideration of its interactions with water. The water-mining relationship must be considered in every possible aspect, not only in the stages of exploration, operation, completion, and post-completion (closure), but also in the processing of the ore, while bearing in mind that the impacts (quality) on water resources may persist for a long time. With the implementation of good practices and the use of appropriate technologies, mine water can be a major asset that forms part of the wider water resource management goals. The status quo now requires that mining companies look towards a more holistic, co-ordinated and inclusive approach towards water use and management that involves collaboration within as well as beyond the boundaries of their operations and businesses.

As previously described, South Africa's rainfall levels are approximately half of the world average; with 80% of the rainfall falling over a period of five months. The country's rivers are small and shallow and have a high rate of evaporation. It is envisaged that by 2030 water supply in South Africa will not be able meet its water demand due to water scarcity and declining water quality. Mining companies are recognising the importance of water in their businesses and if not already, will need to show commitment and concerted effort to combat the issue of water scarcity in South Africa.

Within the current economic climate and risks related to water security, the moment is ideal for the mining sector having specific knowledge on their activities, a good sense of corporate governance and good relationships with technical organizations to either initiate or step up efforts to implement and develop sustainability methodologies and technologies to improve benchmarks, water conservation water demand management being one such sustainability goal. Water challenges are growing and commitment to sustainable management and business performance are vital if mining businesses are to remain competitive and hold a market share.

Corporate Governance

Since the financial crisis in 2008, there has been significant shift in corporate governance at the global, regional, and national levels (IFC, 2016). This is in part due to increased expectations of stakeholders, and also a realization of the contribution that better corporate governance can make to market development, economic growth, and stability.

The following are some of the recent changes in corporate governance:

- A shift to increased regulation, as opposed to voluntary codes, to ensure compliance;
- Increased need for regulators to monitor disclosure on corporate governance codes and practices;
- The need for a long-term view on company affairs and the drivers of such a view, especially in strategy, performance, remuneration incentives, and shareholder expectations;
- Recognition of the importance of understanding the input, business processes, output, and impact of the business model on the company as well as the context it operates within;
- Demand for increased transparency from companies and better information, particularly on governance and board effectiveness.

One of the other major changes in corporate governance is increased transparency and disclosure, with many corporations adopting integrated reporting, which incorporates and connects sustainability and nonfinancial reporting with financial reporting (IFC, 2016). Integrated reporting is based on a new concept of the six capitals—financial, manufactured, intellectual, human, social and relational, and natural capital—that represents the forms of capital or sources that the company employs, transforms, and provides. It tells the story of which capitals the company relies on, how the company uses these capitals, how it transforms them through its business processes and activities into products and services, and the impact of these product and services. Integrated reporting is important in the context of WC/WDM as many companies are now reporting on their water usage, as well as measures taken to reduce their consumption.

Whether in compliance with regulations or through voluntary initiatives, there has been a major shift in corporate reporting to include environment, social and governance (ESG) or sustainability information (IFC 2016). ESH or sustainability reporting was virtually unknown in the 1990s, but by 2000, it had become commonplace and was focused on corporate accountability and performance. From 2000, several different standards and codes were developed to give form and structure to ESG activities and reporting.

Table 28: Global Instruments Addressing ESG / Sustainability Reporting (adapted from IFC, 2016: 48)

Instrument	Year of Introduction / Revision	Development
OECD Guidelines for Multinational Enterprises	• First issued in 1976. • Revised in 2000 and 2011.	• Provides principles for responsible business conduct in employment, industrial relations, human rights, environment, information disclosure, anti-bribery, competition, taxation.
UN Global Compact – 10 Principles	• First issued in 2000.	• A set of principles voluntarily used by many businesses committed to aligning their strategies with UN principles in human rights, labour, the environment, and anti-corruption.
United Nation Principles for Responsible Investment	• First issued in 2006.	• Principles endorsed by institutional investors to incorporate sustainability issues into their investment decision.
International Corporate Governance Network Guidance on Integrated Business Reporting	• First issued in 2015.	• Guidance to companies on investor expectations of corporate reporting, financial and nonfinancial, including environmental and social issues.
Global Reporting Initiative G4 Sustainability Reporting Guidelines	• First issued in 2013.	• Guidelines for companies on the presentation of sustainability information, covering economic, environmental, and social aspects of company activities.
Equator Principles	• First issued in 2003. • Revised in 2013.	• Developed by financial institutions as a financial industry benchmark for assessing environmental and social risks in projects.
Integrated Reporting Initiative	• First issued in 2013.	• Developed by International Integrated Reporting Council to facilitate harmonized and holistic financial and nonfinancial corporate reporting.

In general, companies report on their financial issues in their ‘annual reports’ and nonfinancial issues in their ‘sustainability reports’. The way in which companies approach sustainability, however, varies, depending on their business model and activities (IFC, 2016). In a study by Ernst & Young (2014), more than 50% of companies indicated that sustainability reporting contributed to their competitive advantage by improving company reputation, leading to increased employee loyalty, more reliable company information, and better refinement of the corporate strategy.

Many surveys have been conducted on sustainability reporting (IFC, 2016), with the following being common findings:

- Sustainability reporting is growing;
- Tools to support sustainability reporting are still growing;
- The Chief Financial Officer has a key role in reporting on sustainability, building on their traditional role in reporting;
- Employees are emerging as a driver for sustainability reporting;
- Sustainability rankings and ratings matter to company executives and are reviewed by investor; and
- There is a trend to integrate triple-bottom-line elements of the economic, environmental, and social impacts of business into company reports

Table 29 below presents a summary of current WC/WDM strategies and plans of the world's largest mining houses with respect to the revenue generated based on their latest sustainability reports.

Table 29: Summary of current WC/WDM strategies of the world's largest mining companies

Organisation	Target	Drivers / Reasons for Targets	Mining / Production Figures	Reported water usage	Performance
Anglo American[11]	• By 2020: • Reduce our absolute freshwater intake by 20%. • Recycle / reuse water for 75% of our water requirements. • Improve our water intensity to greater than 1 (i.e. sufficient water to meet mine plan) at all operations.	• ~75% of our current portfolio is located in high-water-risk regions. • Effectively • Managing our water risks and impacts mitigates the risk of operational • Disruptions. • Play a leadership role in our water catchments.	• Diamonds – 27.3 Mct. • Platinum – 2,382 koz. • Copper – 577.1 kt. • Nickel – 44.5 kt. • Niobium & phosphates – 869 kt.	• 190.7 Mm^3	• ~14% reduction from 222.9 Mm^3 to 190.7 Mm^3. • Water use ~23 Mm^3 less water than projected levels. • Total water recycled 66% of total water usage.
BHP Billiton[12]	• All assets with water-related material risks, will set targets and implement projects to reduce their impact on water resources. • Reduce FY2022 freshwater withdrawal by 15% from FY2017 levels. • In line with SDG 6, BHP will collaborate to enable integrated water resource	• Water-related material risks.	• Copper – 1.3 Mt. • Iron ore – 268 Mt. • Coal – 69 Mt. • Nickel – 85 kt.	283.9 Mm^3	• All our assets that identified water-related material risks implemented at least one project to improve the management of associated water resources in FY2017

[11] Anglo American (2016) *Sustainability Report 2016*, http://www.angloamerican.com/~/media/Files/A/Anglo-American-PLC-V2/documents/annual-reporting-2016/downloads/2016-sustainability-report.pdf (accessed on 27 September 2017)
[12] BHP (2017) *Sustainability Report 2017*, http://www.bhp.com/-/media/documents/investors/annual-reports/2017/bhpsustainabilityreport2017.pdf? (accessed on 27 September 2017)

Organisation	Target	Drivers / Reasons for Targets	Mining / Production Figures	Reported water usage	Performance
	management in all catchments where we operate.				
Glencore Xstrata[13]	• Gaining an understanding of its water footprint. • Development and implementation of water management plans covering each of its assets' lifecycles to avoid, minimise or mitigate the impacts and risk. • Improvement of its water management, including identifying and setting water-related targets.	• Recognise that water is a shared and finite resource. • ~20% of its sites are located in areas with extremely high baseline water stress, and ~4% in areas of extremely high-water stress.	• Coal – 124.9 Mt. • Copper – 1.43 Mt. • Ferrometals – 1.52 Mt. • Nickels – 115,100 t. • Zinc – 1.09 Mt.	Water withdrawn: • Coal – 73 Mm^3. • Copper – 350 Mm^3. • Ferrometals – 19 Mm^3. • Nickels – 107 Mm^3. • Zinc – 276 Mm^3.	• Coal – treated and recycled 2.25 Mm^3 in 2016. • Copper – Lomas Bayes in Chile recirculated 90% of the water used by the leaching operation.
Rio Tinto[14]	• Local water performance targets set by managed operations with water risk.	• Water is a valuable global resource and is crucial to our operations. • Comply with Global Reporting Initiative.	• Iron ore – 329.5 Mt. • Bauxite – 29 Mt. • Copper – 523 000 t. • Diamonds – 18 Mct. • Gold – 294 000 oz. • Silver 4 210 000 oz. • Coal – 29.5 Mt.	• Total water withdrawn: • 573 Mm^3. • Water recycled: • 282 Mm^3. • Water returned: • 495 Mm^3. • Evaporation and other losses: • 640 Mm^3.	• Group-wide water risk assessment conducted in 2011. • ~67% of its managed operations were on track to meet their local water performance targets by 2018. • Implement management activities to bring operations not on target back on track.

[13] Glencore (2017), Glencore Sustainability Report 2016, http://www.glencore.com/assets/sustainability/doc/sd_reports/2016-Glencore-Sustainabilty-Report.pdf (accessed on 27 September 2017)
[14] Rio Tinto (2016) Rio Tinto Sustainable Development Report 2016, www.riotinto.com (accessed on 27 September 2017)

Organisation	Target	Drivers / Reasons for Targets	Mining / Production Figures	Reported water usage	Performance
				• Entrained in product or process waste: • 37 Mm^3.	• Implement ICMM position statement on water stewardship;
Vale[15]	• Monitor total water collected and in particular the use of water collected from • The environment in the Vale's production processes. • Monitor total volume and percentage of water reused – encourage use of less noble water resources, reducing the use of water collected from the environment in the Vale's production processes.	• Operations in water risk areas (~64.9% in low-medium risk; ~5.6% in medium-high risk; ~8% in high risk). • Commitment to recirculation of water in Vale's Sustainability Action Plan. • Align with Global Reporting Initiative.	• Iron ore – 348.8 Mt. • Copper – 453 000 t. • Nickel – 311 000 t. • Cobalt – 5 800 t.	• Water withdrawn – 426 Mm^3 (32 Mm^3 not used). • Water used – 394 Mm^3. • Water recirculated / reused – 1,614 Mm^3 (~80%). • Water discharged – 195 Mm^3.	• Reached water resources target at its 5 iron ore sites – Average 25% reduction in water use. • Reached water resources target at its 2 base metal sites – Average 38% reduction in water use. • Revised guidelines for water resources to align with Global Reporting Initiative.

[15] Vale (2016) *Sustainability Report 2016*, www.vale.com (accessed on 28 September 2017)

Similarly, to the international trend, many South African companies were early adopters of integrated reporting as a means of reporting in an integrated way on financial and sustainability matters as required by Johannesburg Stock Exchange (JSE) Listing Rules in 2010 (on an apply-or-explain basis) (IFC, 2016). Integrated reporting, which incorporates sustainability considerations is also a requirement of the voluntary standard King III Code (2009), the South African corporate governance code. As mentioned previously, integrated reporting is important in the context of WC/WDM as mining companies for example are now required to report on their water usage and measures taken to reduce their consumption.

The King Report on Corporate Governance in South Africa first included a requirement for integrated reporting in King III Code for Governance Principles in 2009. In order to support the implementation of the code, the South African Integrated Reporting Committee (IRC) developed a guidance document entitled "Preparing an Integrated Report: A Starter's Guide" based largely on the International <IR> Framework.

Many studies have examined the South African story of integrated reporting as the country is considered as a leader in integrated reporting development as well as in governance and culture (IFC, 2016). For example, a recent study by the South African Institute of Chartered Accountants (SAICA, 2015) found the following:

- Several of the top 100 JSE listed companies and leading state-owned entities have recognized the benefits of integrated thinking;
- Over 70% of companies confirmed that integrated reporting has been a driver for achieving integrated thinking; and
- Over 70% of executives and non-executive directors surveyed felt that decision making at management and board levels had improved as a result of integrated thinking.

Adequate quantities of water, of a suitable quality, are a necessity for mining in the country, which utilises approximately 6% of the water resources. The use of water in mining covers a wide variety of processes, including, amongst others potable water, cooling water and water as a transport medium. Water is a major requirement in the mining industry, with large volumes being used in direct mining operation through the use of hydraulic drills, cooling and dust suppression, in the metallurgical and refining operations, ore processing and the transportation of wastes to mine residue disposal facilities such as slimes dams and stockpiles.

Mine water management within the context of catchment wide resource management requires an integration of the water quality and quantity interventions to prevent the deterioration of water resources, but also to ensure efficient, beneficial and sustainable use thereof. The DWS has developed Reconciliation and Water Quality Management strategies using these interventions for various catchment areas that specify measures to curb and manage the anticipated effects of impacts such as on water quality, e.g. salinisation and eutrophication on river systems, noting the contribution of mine drainage to salt loadings where identified. The collective aim of these strategies is to ensure continued water security in the medium to long term (DWA, 2010)

APPENDIX 3 – WATER RESOURCES IN SOUTH AFRICA

OVERVIEW

Due to the poor spatial distribution of rainfall, the natural availability of water across the country is also highly uneven. South Africa has a predominantly semi-arid climate, varying from desert and semi-desert in the west to sub-humid along the eastern coastal area. This situation is compounded by the strong seasonality of rainfall, as well as high within-season variability, over virtually the entire country. Consequently, surface runoff is also highly variable. It reduces far more sharply than a reduction in rainfall due to high evaporation losses. As a result, stream flow in South African rivers is at relatively low levels for most of the time. The sporadic high flows that do occur limit the proportion of stream flow that can be relied upon to be available for use (NWRS, 2004). Groundwater plays a pivotal role in especially rural water supplies. Increasing challenges from water pollution also pose constraints on the available water resources for use.

South Africa's water security is largely reliant on surface water resources. South Africa is a water scarce country and the water supply situation may worsen if unfavourable climatic changes should arise from global warming. Reduction in surface water availability will soon be insufficient to meet the country's growing development needs. Current projections indicate that water demand in South Africa will increase by 1% each year, resulting in a water supply deficit by 2030, possibly sooner.

Most of South Africa's key economic centres are located in areas of low water availability, resulting in local demand exceeding supply in many of the centres. However, the country has a highly integrated bulk water supply system that includes many large dams – the highest number in Africa – and many interbasin transfers to balance supply and demand. Wise utilisation of this resource in a sustainable manner is, therefore, essential for the future of the country. South Africa will soon face a water shortage if the current risks are not taken seriously and interventions applied timeously.

Four of the main rivers in South Africa, Limpopo, Inkomati, Pongola and Orange Rivers are shared with other countries. These rivers together drain about 60% of the land area and contribute over 40% of the country's total surface runoff (NWRS, 2004).

MAJOR RIVER SYSTEMS

The river drainage network in South Africa is very asymmetrical. The great escarpment separates South African rivers into two groups, *viz*. the plateau rivers and those of the marginal areas. The eastern marginal area, covering 13% of the country, accounts for 43% of the total run-off. This is derived from several short steep rivers which rise on the slopes and flow directly into the Indian Ocean. The longer east-flowing rivers in the north, such as the Limpopo, the Komati, the Crocodile and the Olifants rise on the interior plateau and have broken through the escarpment (Sancold, 1994). The Vaal and Orange rivers rise almost on the eastern escarpment and flow across the entire country to discharge into the Atlantic Ocean. Most of the remaining rivers drain the escarpment and coastal areas and have relatively small catchments.

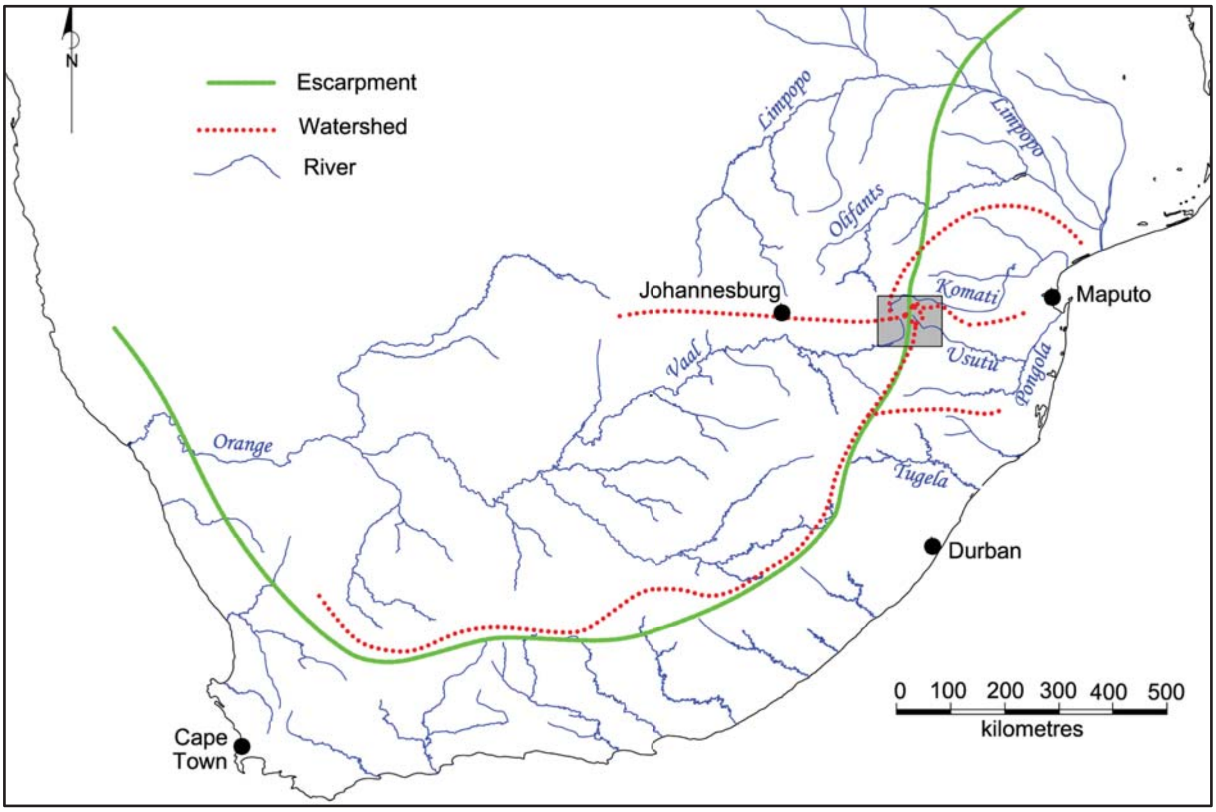

Figure 71: Major River basins in South Africa (McCarthy 2011)

Most of the plateau is drained by the large Orange River System which flows westwards to the Atlantic Ocean. Although its catchment area comprises 48% of South Africa, it contributes only 22% of the total mean annual runoff because the rainfall reduces towards the west where evaporation is high. Its major tributaries are the Caledon and Vaal rivers. Downstream of its confluence with the Vaal, there is almost no addition to its runoff over a distance of 1200 km. No water is known to have reached this reach of river from the large Molopo-Nossob system situated to the northwest for centuries. In the South-Western Cape, the major rivers are the Gamtoos, Gouritz, Breede, Berg and Olifants progressing westwards from the year-round rainfall area to the winter rainfall area.

WATER RESOURCE MANAGEMENT IN SOUTH AFRICA

The DWS as the custodian of the country's water resources aims to achieve the co-ordinated development and management of water resources. Because the water resource cannot be considered separately from the people who use it, a balanced mix of technological and social approaches is used to achieve integrated management.

The NWA (Act 36 of 1998) includes a range of strategies, management instruments and regulatory measures and interventions that are applied to management of water resources South Africa, *viz.*:

- The National Water Resource Strategy (NWRS);

- Catchment Management Strategies;
- Water Reconciliation Strategies;
- Water Resource Allocation Plans;
- Resource Directed Measures (RDM) – defining the desired level of protection for a water resource, and on that basis, setting the Reserve as well as clear numerical or narrative goals of the resource (the RQOs). These measures focus on the quality of the resource itself;
- Source Directed Controls (SDCs) – controlling impacts on the water resource through the use of regulatory measures such as registration, permits, directives and prosecution, and economic incentives such as levies and fees, in order to ensure that Resource Quality Objectives (RQOs) are met. These measures contribute to defining the limits and constraints that should be imposed on the use of water resources to achieve the desired level of protection;
- Managing demands on water resources to keep utilisation within the limits for protection; including water conservation and demand management; and
- Monitoring the status of the country's water resources to ensure that the RQOs are being met, and to enable the modification of programmes for resource management and impact control as and when necessary.

It is the Department's responsibility to also ensure that South Africa's scarce resources are made available to meet the country's needs. The Department needs to ensure water security, healthy ecosystems, development of water resources that supports economic growth; meets domestic and social needs and improves the overall quality of life. This requires a mix of all of the above measures within the various catchment areas and growth points throughout of South Africa. However, while in place since the implementation of the NWA, from a water resource governance and regulatory point, many of the instruments have not been fully or adequately implemented or achieved to the extent necessary, in order to meet the desired outcomes. Water scarcity (quantitative and qualitative) is a reality, arising not only from physical limits, but also from inefficient use and poor management. A renewed, collective effort from national, provincial and local government, key role players, stakeholders and citizens is required to ensure water resources are sustainably managed to meet current water resource challenges faced by the country (both in water quality and quantity).

Growth in water demands in the economic sector, urbanisation and industrialisation over the last decade has seen intense pressure being placed on scarce water resources which is compounded by deteriorating water quality that is adding to security of water supply. While South Africa has well developed surface water resources infrastructure the country has seen and is approaching full utilisation in many catchment areas, and with changing climate patterns, water security is a potential risk. Alternate sources of water will have to be embraced – groundwater, re-use of water and desalination all playing an increasing role in future.

While enough water is available for South Africa to stay in business, it requires a range of measures be implemented to avoid and limit risks to water shortages. The DWS has identified the following (DWA, 2010; NWRS2, 2013):

- Investing in Water Conservation and Water Demand Management as the foremost strategy in reconciling the water balance (water use efficiency measures at all levels; across all sectors; all water uses, nationally);
- Increasing the use of groundwater resources – as a source to primarily supplement domestic water supply;
- The re-use of water is another key strategy specifically in areas where freshwater resources are limited (which may include treatment and use by industry, irrigation or for potable purposes);
- Investing in sea water desalination and other new technologies to make more water available;
- Management of water quality specifically to address pollution impacts from wastewater treatment plants and from acid mine drainage;
- Development of water resources and inter-basin transfers in catchment areas where viable and strategic; and
- Long term planning and monitoring.

Water development potential only exists in a limited water management area, whilst serious constraints are present in the remaining water management areas. Implementation of the above measures as alternate sources of water is necessary to ensure water supply meets the growing demands.

The typical increasing cost of different water sources is reflected conceptually Figure 72. Water re-use must be considered as one of the suite of options to augment water supply, once the conventional fresh water resources are fully developed or the cost of water re-use becomes comparable to development of conventional water sources. The economic value/cost of water must also be seen in the broader context of affordability, reliability and responsible use of a limited resource (DWA, 2011).

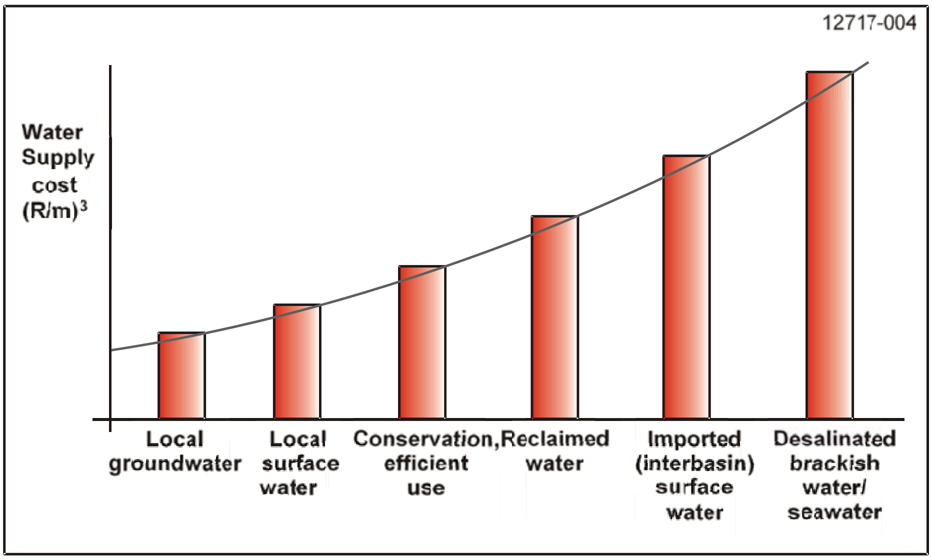

Figure 72: Increasing cost of water treatment

APPENDIX 4 – WATER MANAGEMENT PERSPECTIVE

INTRODUCTION

Management of the country's water resources, is facilitated through the delineation of 9 catchment-based water management areas (WMAs), shown in Figure 73. The boundaries of the water management areas lie mostly along the divides between surface water catchments/ drainage regions and aquifer boundaries.

The 9 WMAs include the:

- Limpopo WMA,
- Olifants WMA,
- Inkomati-Usuthu WMA,
- Pongola-Mtamvuna WMA,
- Vaal WMA,
- Orange WMA
- Mzimvubu-Tsitsikamma WMA,
- Breede-Gouritz WMA, and
- Berg-Olifants WMA.

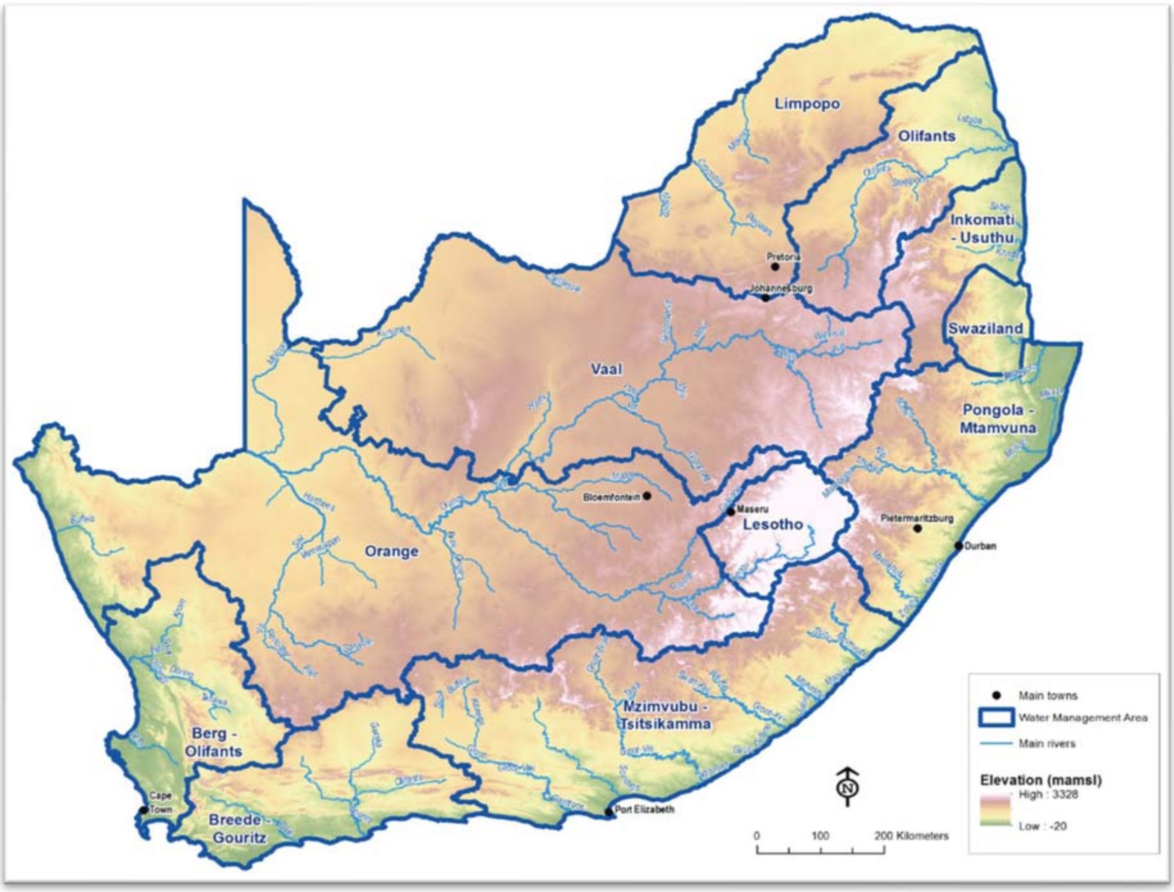

Figure 73: Water Management Areas of South Africa

Pronounced differences are evident among the WMAs with respect to water availability and water requirements, which are attributable to the large spatial variations in climate, water resources, the level and nature of economic development and population characteristics, which requires further spatial differentiation. WMAs were therefore further divided into sub-areas to enable improved representation of the water resources situation in the country and for strategic management purposes.

Each WMA in terms of its sub-areas is briefly discussed below to provide a perspective on the water resources situation.

THE LIMPOPO WMA

The Limpopo Water Management Area is large and complex and comprises the Crocodile West, Marico, Limpopo and Luvuvhu catchment sub-areas. Much of the area has low rainfall with significant inter-dependencies for water resources between catchments and with neighbouring WMAs (the Crocodile-West catchment and Olifants catchments).

The dry Limpopo River catchment area includes the Matlabas, Mokolo, Lephalala, Mogalakwena, Sand, Nzhelele and Nwanedi sub-catchments. The main urban areas within the WMA include Mokopane, Polokwane, Mookgophong, Modimolle, Lephalale, Louis Trichardt and Musina. The land-use is agriculture (livestock and irrigation farming), with private and provincial nature reserves as well as coal mining and platinum mining. The area is largely rural in nature. The Nylsvlei wetland between Modimolle and Mookgophong is the country's largest ephemeral floodplain and has been declared a RAMSAR wetland site because of its international conservation importance and birdlife.

Much of the surface water potential in the catchment has largely been developed, with no opportunity for new dams. Groundwater is used extensively in the catchment. However, over exploitation occurs in certain areas largely due to the irrigation sector. Several inter-water management area transfers exist, bringing water into the area from the Olifants (at Olifantspoort) and Letaba (Dap Naudé and Ebenezer Dams) catchments. There is also a planned transfer of water from the middle Olifants catchment to support new and existing platinum mines along the eastern limb of the Bushveld Igneous Complex (Mokopane area). Currently these mines get purified wastewater from the Polokwane wastewater treatment works. A further water transfer from the Steelpoort catchment is also planned to support the domestic water requirements of Polokwane.

The large Mokolo Dam is situated in this catchment, which provides water for a multitude of uses. The main industrial development relates to Eskom's Matimba Power Station and the newly constructed Medupi Power Station. A transfer from the Crocodile West catchment into the Mokolo catchment is being planned to support the expected growth in mining and power generation in the Lephalale area (MCWAP Project), however, this is will happen only once optimisation of the utilisation of local water resources has occurred. The Mokolo catchment is the dominant coal mining area and is largely situated on the Waterberg coal fields, which is considered to hold more than 40% of South Africa's *in situ* mineable coal reserves. There are opportunities for further development of the substantial coal reserves and gas fields and other coal-based industries and related development. These vast resources are presently being mined at the large Grootegeluk coal mine. Other larger mining operations in the Limpopo catchment include the Venetia diamond mine, Vele Coal mine, Makhado Coal Mine, and the Amandelbult, Northam, Potgietersrust, Messina, Lebowa, Marula and Modikwa platinum mines. Further expansion of mining is planned, particularly in the Mokopane area which will increase water requirements significantly. The water resources, especially surface water resources, are heavily stressed due to the present levels of development and require interventions to meet future demands. It is crucial that water supply is secured and well managed (LNRS, 2015). Groundwater resources must be protected from contamination, and the water quality of surface water resources must be improved in heavily impacted areas. Driving WCWDM initiatives and options for use of treated effluent from the local municipalities, the transfer of water allocations, further groundwater development, elimination of unlawful irrigation, infrastructure developments and water transfers from the Olifants River basin are being investigated to supplement water supply.

The Luvuvhu River sub-catchment is situated to the north east of the Limpopo WMA and include the Mutale, Mutshindudi and Dzondo Rivers as tributaries. The main urban area is Thohoyandou with a large rural population scattered throughout the area. The economy is driven by irrigation and commercial forestry. Large scale utilization of the groundwater resource occurs mostly downstream of the Albasini Dam where it is used by irrigators and in the vicinity of Thohoyandou where it is used to provide water to rural communities. Several major dams have been developed to augment water supply, most recent being the Nandoni Dam. However, no scope for further storage is available. Verification of water use, reduction of canal losses and some curtailment of irrigation water use maybe required to balance water requirements with water availability.

The Marico catchment borders Botswana to the northwest and the Vaal WMA to the south. The catchment is a large, relatively flat basin with low rainfall. Surface water is limited. Groundwater is important with springs and eyes providing river base flows and dolomitic aquifers providing water supply to the neighbouring Mafikeng area. The catchment is predominantly rural, with the main economic activity and water use being irrigated agriculture. Major towns include Zeerust and Marico. Some mining activity is present in the catchment but this is limited. Water supply is limited in the Marico, and sources are over exploited, with resources fully developed (NWRS2, 2013). The system is under stress and current water uses must be well managed and controlled. The catchment will require intensified water conservation and demand management efforts, validation and verification of water uses, further groundwater resource development, water quality improvement on a localised scale; reduction of water allocations, improved system operation to support future growth in water requirements.

The Crocodile West catchment lies to south eastern portion of the Limpopo WMA. It is the second most populous catchment area in the country, with the largest proportionate contribution to the national economy, generating almost a third of the country's Gross Domestic Product. The area is highly altered by development, with economic activity dominated by urban areas and industrial complexes of northern Johannesburg and Tshwane and with platinum mining north-east of Rustenburg. Extensive irrigation activities occur along the major rivers, with game and livestock farming occurring in other parts of the catchment. Development and utilisation of surface water occurring naturally in the catchment has reached its full potential. Large dolomitic groundwater aquifers occur along the southern part of the area which are utilised extensively for urban and irrigation purposes. A substantial portion of the water used in the catchment is transferred from the Vaal River and further afield. Increasing quantities of effluent return flow from urban and industrial areas offer considerable potential for re-use, but the effluent is at the same time a major cause of pollution in some rivers. Population and economic growth, centred on the Johannesburg-Pretoria metropolitan complex and mining developments, are expected to continue strongly in this area. Domestic water supply to the catchment will continue to be supplied from the Vaal River catchment by Rand water. Areas north of the Magaliesberg will utilise the increasing return flows from treated effluent from the metropolitan areas as the future source of water. The management of water quality in the system is a key priority to ensure usability of the water resource. The excess return flows (surplus water) from the Crocodile West catchment will be transferred to the Lephalale area. Demand side management interventions and possible sources of treated effluent from the Vaal River catchment will be considered to address any shortfall in water requirements (CWRSS, 2012).

It is also important that the mining sector within the Limpopo WMA provide annual updates of historic water use and future water requirement projections to enable more accurate water balance for the various catchment to be determined. This will support improved long-term water projections and allow appropriate reconciliation options to be investigated and/or adjusted.

Much of the deterioration in water quality where identified is linked to anthropogenic development and associated impacts, which include irrigation return flows, urbanisation, wastewater discharges and mining activities. The Crocodile River and many of its main sub-systems are in a poor water quality state. Options to reuse treated wastewater effluent and excess mine water will assist alleviating and improving the current water quality condition in impacted areas. However, this would need to be managed with balancing the requirement for surpluses to remain in the system to support water transfers and ecological flow requirements.

The four major mineral provinces in the WMA, the Witwatersrand basin, BIC, Transvaal Supergroup and Karoo coalfields all present the risk of acid mine drainage and pollution of water resources by toxic trace elements due to mining activity in the WMA.

OLIFANTS WMA

The Olifants WMA comprises the Olifants, Letaba and Shingwedzi River catchment areas. The WMA is highly stressed, fast growing in terms of population and development. There is very little opportunity for further water resource development and future development will need to rely on local sources of water.

The Shingwidzi River is the northernmost river of the Olifants River WMA, joining it at the lower end of its basin. The Shingwidzi is a seasonal river whose riverbed is dry for prolonged periods. It includes the major tributaries the Shisha, Mphongolo and Phugwane drain the Shingwidzi River catchment, which falls largely in the Kruger National Park. Outside the park, land use is mainly subsistence agriculture and informal urban settlements. Several small gold mines were developed in the southwestern part of the Shingwedzi River catchment. The mines have limited impact on the local economy and have been closed down in recent years. There are no major dams in these sub-areas because of the limited water resources and the non-availability of suitable sites. Some small dams have, however, been constructed in the Kruger National Park for game watering. Of these, the most notable are the Kanniedood Dam on the Shingwedzi River and the Engelhard Dam on the Letaba River. The Makuleke Dam is in the Mphongolo River.

For many water users, groundwater constitutes the only dependable source of water and its utilisation is of major importance. A large proportion of the rural domestic and stock watering requirements are supplied from groundwater for most of the rural settlements and villages. Groundwater is also used for game watering.

The Letaba catchment is located to the north of the WMA in the Limpopo Province and is drained by the Groot Letaba River and its major tributaries the Klein Letaba, Middle Letaba, Letsitele and Molototsi rivers. The catchment includes the main urban areas of Tzaneen and Nkowakowa and the Klein Letaba River catchment the town of Giyani. The rural population is scattered throughout the catchment area. The Letaba River catchment is highly regulated particularly in the upper catchments where most of the runoff is generated. Surface water mainly originates in the mountainous areas and is regulated by several dams in the upper (Tzaneen, Middle Letaba and Ebenezer dams) and middle reaches of the river. The Letaba River is further regulated by a series of irrigation weirs that limit the flows of water into the Kruger National Park. There are further regulatory weirs and dams within the Kruger National Park (Mingerhout Engelhardt dams). Intensive irrigation farming is practised in the upper parts of the Klein Letaba River catchment (upstream and downstream of the Middle Letaba Dam), and particularly along the Groot Letaba (downstream of the Tzaneen Dam) and Letsitele rivers. Vegetables, citrus and a variety of fruits are grown. The smaller Giyani (Sutherland) greenstone belt in the Klein Letaba catchment, in the area around Giyani, has yielded at least 10 t of gold from numerous small and six larger deposits (all closed at present), namely the Klein Letaba, Franke, Birthday, Fumani, Golden Osprey and Louis Moore mines. Large magnesite deposits were exploited here in the past. It is believed there is further potential for gold in this belt.

The surface water resources within the Letaba catchment are extensively developed. Faced with water shortages of increasing severity and frequency over the years, the main consumptive users of water have from time to time compete for the limited supplies and experienced significant levels of restrictions. This has resulted in the degradation of the riverine ecosystem. The existing limited water resources in the catchment have been overexploited to meet the irrigation, afforestation, industry, mining and rapidly increasing domestic water demands. There is a lot of water wastage and inefficient use, which if reduced and properly manage will alleviate some of the stress being experienced.

Some development projects are underway to increase the additional storage capacity of the dams in the Letaba catchment and to supplement domestic water supply, which includes the Groot Letaba Water Development Project. Intensified WCWDM measures and exploration of alternate water sources within the catchment are required to support growing water demands. Current inefficiencies, losses and poor management need to be addressed. Additional monitoring of flows and dam balances are required. Groundwater opportunities for augmentation are available as a sustainable water source and should be investigated.

The Olifants system forms the major part of the WMA catchment area. Its main tributaries include the Wilge, Elands, Ga-Selati, Klein-Olifants, Steelpoort, Blyde, Klasserie and Timbavati. The Olifants catchment is a highly utilised and regulated catchment. Available water resources are not sufficient to meet the requirements of users and this is one of South Africa’s most stressed catchments in terms of both water quantity and water quality. There is limited opportunity for further water resource development and future water supply will need to rely on local sources of water.

The main economic activity in the catchment is related to coal, platinum, vanadium, chrome, copper and phosphate mining. There are also large steel foundries located in Middelburg and Witbank. Extensive irrigation occurs in the vicinity of the Loskop Dam, along the lower reaches of the Olifants River, near the confluence of the Blyde and Olifants rivers, as well as in the Steelpoort valley and upper Selati catchment. Much of the central and north western areas of the catchment area are largely undeveloped. Witbank, Middelburg and Phalaborwa are the largest urban centres. While most of the catchment area remains under natural vegetation for livestock and game farming as well as conservation, severe overgrazing is prevalent in many areas. Afforestation is found in some of the higher rainfall areas, with notable plantations in the upper Blyde River valley. The Kruger National Park is located at the downstream extremity of the Olifants catchment area. Most surface runoff originates from the higher rainfall southern and mountainous areas. There are 9 major dams constructed in the Olifants River and the major tributaries which regulate the flow in the river system.

The coal mining is located in the upper reaches of the catchment around eMalahleni, Middelburg and Delmas, associated with large thermal power stations. The platinum, chrome and vanadium mines are located in the Steelpoort and Middle Olifants areas of the WMA while the copper and phosphate mining occurs in the lower Olifants around Phalaborwa. The catchment includes all or part of the Witbank, Highveld, Eastern Transvaal, South Rand and KaNgwane coalfields and the undeveloped Springbok Flats coalfield. This is the most important coal-producing area in South Africa and supports some 65 collieries working several seams in the Ecca coal belt. The Phalaborwa Complex contains large deposits of copper, magnetite (iron ore), zirconium, uranothorianite, nickel, precious metals and apatite (phosphates), as well as the world's largest deposit of vermiculite. Silica, chromite and vanadiferous magnetite deposits mined in the Steelpoort area serve as feedstock for ferrochrome, ferromanganese, ferrosilicon, and ferrovanadium production facilities.

The WMA is in a water deficit and options that are either underway or being investigated include implementation of WCWDM as a priority in all sectors, the use of excess mine water and treated wastewater effluent; development of groundwater resources, water trading where water saved through agricultural allocations could be moved into mining and industrial sectors and elimination of unlawful water use. The Olifants River system also faces a number of water quality challenges impacting on both surface water and groundwater including salinisation, sedimentation, nutrient enrichment and microbial and agrochemical pollution, all at different scales within the sub-catchments of the WMA.

Water for Polokwane and Mokopane supply areas will be augmented from the Olifants catchment.

Of specific importance in the Olifants WMA, is the management of mining activities which is crucial to the management of water quality both in the short term to alleviate the current salt loads being released and long term to manage the impacts of mine closure and mine decants. There are a number of defunct mines in the catchment. Some of these mines are abandoned (ownerless) and are decanting into the river system. Acid mine drainage from abandoned and operational coal mines is impacting on the Olifants, specifically in the upper catchment. A major intervention in terms of current mining and future development practices is required if the upper Olifants river catchment is to remain sustainable.

A controlled release scheme started in 1996 has been used to manage the excess mine water from the mines in the upper catchment. However, this scheme is no longer able to deal with the growth in the volumes of excess water and there is insufficient assimilative capacity available in the system. Urgent attention is required to upgrade the water management system to achieve compliance.

A critical threat to the system is the mine water decant from the mine workings of a number of mines reaching the end of their economic lives in the Upper Olifants catchment. This water will be polluted and the volumes will be large enough to impact significantly on the regional water quality. Many mines are working towards reducing all raw water inputs through several reuse interventions inside the fence. Plans and interventions to treat and manage the excess mine water are being developed by the major mining houses. Mine water reclamation schemes have already been constructed which are supplying water for potable use to the local municipalities (EMalahleni). These schemes have to be developed and coordinated to address the future decants. The reclamation of the excess mine water has been earmarked as the future source of water to meet the growing water requirements in the upper areas of the Olifants catchment (DWS, 2016).

INKOMATI-USUTHU WMA

The Inkomati-Usuthu WMA is situated in the north-eastern part of South Africa and borders on Mozambique and Swaziland and forms a part of the Inkomati International River Basin which is shared between the Republic of Mozambique, the Kingdom of Swaziland and the Republic of South Africa. All rivers from this area flow through Mozambique to the Indian Ocean. The WMA includes the Sabie-Sand River system, the Crocodile River (East) system, the Komati and Lomati system and the Usuthu River system. The Kruger National Park occupies almost 37% of the land area of the WMA, and it a key feature.

Economic activity in the WMA is mainly centred on commercial farming, as the largest water user, with related industries and commerce, and a strong eco-tourism industry. There is an emergence of increased coal mining in upper parts of the catchment. Mining is the dominant contributor to the (water based) GDP of the basin, followed by industry, irrigation and forestry (IUCMS, 2018). The Sabie River which flows through the Kruger National park is ecologically one of the most important rivers in South Africa. Important urban centres are Mbombela, White River, Komatipoort, Carolina, Badplaas, Barberton, Sabie, Bushbuckridge, Kanyamazan, Matsulu, Lothair, Piet Retief and Amsterdam. Mbombela is the largest urban centre in the water management area. Scattered rural villages with a high population density are characteristic of the area.

Dams have been constructed on all the main rivers or their tributaries, and water resource system (dams) in the WMA are generally well regulated. The water resources of the river systems are fully utilised or in balance, which requires reconciliation options for future water supply. An important feature is the joint management by South Africa and Swaziland of part of the water resources of the Komati Basin Water Authority (KOBWA). Because of the well-watered nature of most of the area, groundwater utilisation is relatively small. Most of the present yield from the Komati River west of Swaziland is transferred to the Olifants WMA for power generation (Vygeboom and Nooitgedacht dams). As in the case of the Komati, much of the available water from the Usuthu system is transferred out of the catchment (from Jericho, Westoe, Heyshope and Morgenstond dams) for use by the power stations on the Highveld. The Inkomati River is subject to an international cooperative agreement with Mozambique which obligates South Africa to have a minimum of 2 m^3/s supplied to Mozambique. Swaziland is also very dependent on the Usuthu River and relies on responsible upstream use by South Africa.

Large areas at several locations have been developed under irrigation. The crops grown include fodder, grain, tobacco, citrus, tropical fruits and sugar. Dry land cultivation is found where good soils and favourable topography occur. The upper catchment of the Sabie River is densely commercially afforested. The land use of the middle reaches is a mixture in sub-tropical fruits and dense informal settlements. The lower reach lies within the Kruger National Park. The upper Crocodile River catchment has intensive afforestation and agriculture of sub-tropical fruits and nuts. The flow of the Crocodile River is regulated by the Kwena Dam in the upper catchment. The upper Usuthu catchment is sparsely populated. Land use in the Usuthu system is dominated by afforestation, with some limited irrigation.

The major mining activity within the Inkomati catchment occurs in the Barberton and Mbombela areas, in the Crocodile River catchment (Kaap River). The mineral deposits in this region include gold, asbestos, iron, nickel, copper and manganese and a significant number of coal reserves. Gold and other minerals were widely mined but have reduced to mainly small-scale operations. Extensive coal mining is found in the south-west of the water management area, which is mainly used as fuel for large thermal power stations at the divide with the neighbouring Olifants WMA.

Water quality in the WMA is generally, good with identified hotspots of concern. Areas in the Elands, Kaap and Crocodile (downstream) are impacted in terms of water quality. Salinisation of water resources and microbiological pollution due to untreated or partially treated sewage is of growing concern.

The catchment is a critical element of an internationally renowned conservation area and international tourist hot spot both of which are dependent on healthy aquatic systems and good water supply. The rivers are an important source of water for both Mozambique and Swaziland

Currently the major stresses facing the WMA are the high water demands by Eskom, irrigation, afforestation and industry and rapidly increasing domestic water demands. Water is over-allocated and requirements exceed supply. No new water is available for allocation. The situation is managed by voluntary water restrictions specifically so in the Crocodile (East) catchment.

Transfers of water into this WMA from elsewhere in South Africa are not feasible given distance from all other sources. Some opportunities exist for new dams and augmentation through water transfers and regional schemes to make more water available. Water resource deficits will have to be met from within the WMA through more efficient use of the limited resources and eradication of unlawful water uses. Conjunctive use of surface and groundwater is essential if all requirements are to be met.

WCWDM is the primary strategy to address the management of water demand as well improved management and maintenance of infrastructure. Transfer of water use allocation from irrigation to domestic use also exists.

PONGOLA-MTAMVUNA WMA

The Pongola to Mtamvuna WMA comprises the Mhlatuze, Pongola, Mkuze, Mfolozi, Thukela, Mngeni, Mvoti, Mkomazi, Mtamvuna and Mzimkulu systems. These systems vary in size from medium to very large catchment areas with all rivers flowing directly in the sea, apart from the Pongola River which confluences with the Maputo River in Mozambique. There are some water transfers across catchments, the most important being the transfer of water from the Thukela system to the Vaal system, with additional water being reserved for long term requirements. The current critical issue facing the WMA is the additional water supply needed to meet the growing requirements of the KwaZulu-Natal Coastal Metropolitan Area (Durban-Pietermaritzburg, KwaDukuza in the north to Amanzimtoti in the south). Water requirements are still increasing, with systems already in deficit. Currently, the Thukela pipeline project, the raising of Hazelmere Dam and the building of Spring Grove Dam are underway as interventions to address water shortages. Further options being investigated are dams on the Mkomazi and Mvoti rivers as well as desalination and re-use of wastewater.

Mhlathuze, Mfolozi, Mkuze and the Pongola catchment areas include industrial, agricultural and transportation as the key economic sectors. Land use in the catchment area, from a water resources perspective, is dominated by irrigation and afforestation. A large portion of the catchment is tribal land which is typically used for stock farming. There are old mining areas in the vicinity of Vryheid. The Richards Bay area is a fast-growing industrial hub with a number of industrial complexes within the Mhlatuze catchment. The majority of the population in the catchment live in rural areas. The Pongola System includes the massive Pongolapoort Dam which supports the Pongola Irrigation Scheme and the Bivane Dam upstream which provides irrigation water to sugar cane farmers. The Mkuze and Mfolozi catchments are large unregulated catchments, supporting primarily forestry and irrigation water use. The catchment includes the world-famous heritage site, Lake St Lucia. Upstream water use, poor catchment management and erosion in the catchment have impacted on the ecological condition of the St Lucia estuary. There is some surplus water available and the potential for water resource development within this wider catchment area. Sufficient water is available to meet domestic needs and the growing irrigation water requirements.

The Thukela River is the largest river within the WMA, and includes Little Thukela, Klip, Bloukrans, Bushmans, Sundays, Mooi and Buffalo rivers as its major tributaries. The resources of the Thukela River are used to support requirements for water in other parts of the country, with large transfers of water to neighbouring catchments. The river is relied upon for transfers into the Vaal System, and to the Mhlatuze catchment to its north and Mooi-Mgeni system to the south. Eight major dams within the catchment include Woodstock, Spioenkop, Zaaihoek, Driel Barrage, Kilburn, Ntshingwayo, Craigie Burn and Wagendrift Dams. The catchment includes the major towns of Newscastle, Dundee, Ladysmith and Estcourt. Most people in the catchment are dependent on agriculture for their livelihood. Subsistence farming is practised on communal land, which covers much of the catchment area. The catchment also includes a paper mill at Mandini. Coal mining is also predominant in the Thukela catchment. The main mining area is the Buffalo River catchment. A number of other commodities such as sand and dolerite are also mined. Although many of the collieries in WMA are inactive, they impact on the quality of the water resources in the area. The economy of the Newcastle area is heavily dependent on mining activity. The natural drainage from geological formations but especially from coal mine workings also contains appreciable amounts of nitrates and phosphate. The water resources system supply in the Thukela catchment is in balance. Some tributary catchments in the Thukela are in a water deficit. There is potential for further development to support local water requirements but this would need to be balanced with the future augmentation schemes that has water reserved for the Vaal River system.

The Mngeni, Mvoti, Mdloti, Mzimkulu and Mtamvuna systems form the southern portion of the WMA. The Mzimkulu and Mkomazi comprise the two larger river systems, the Mngeni and Mvoti the two medium-sized and the Mzumbe, Mdloti, Tongaat, Ifafa, Lovu and Mtamvuna as several smaller river systems. The Mvoti, Mdloti and Mngeni catchment areas are stressed with water requirements exceeding the available water supply. The catchment area makes the fourth largest contribution to the GDP of the national economy. The predominant land uses are dominated by major urban settlements along the Durban-Pietermaritzburg axis. The Durban metropolitan area is one of the major urban areas in South Africa. Several small urban settlements are located in the hinterland and support the surrounding agricultural sector. Outside of the urban areas there are large tracts of commercial and subsistence agricultural land. Timber, sugar cane, pastures and cash crops are the dominant land uses in the commercial agricultural areas. There is substantial industrial development in the urban areas of Durban, Stanger and Pietermaritzburg. There are no significant mining concerns or power stations situated in the catchment.

The main product of the mining industry in the Mhlatuze catchment is coal. Iscor Hillendale Mine mines Zircon. Although the many collieries are assumed inactive, water decant from these collieries impacts on the quality of the water resources in the area. The catchment also includes Richards Bay Minerals, heavy mineral sands producing titanium and zirconium

Prioritised interventions to address water supply, in addition to the priority infrastructure projects underway include management of short-term deficits through the continuous implementation of WCWDM, wastewater re-use, desalination options and development of bulk water supply schemes.

VAAL WMA

The Vaal WMA includes the Upper, Middle and Lower Vaal catchment areas. The Vaal River is the major water resource within the catchment with a number of significant tributaries along its length. The Vaal River is South Africa's most important river because it supplies water to the economic heartland of the country, not only in the Gauteng region but as far afield as the mining districts of Welkom, Sishen and Postmasburg. It is already over-utilised, necessitating inter-basin transfers from the Tugela (via the Tugela pumped storage scheme) and the Senqu Rivers (via the Lesotho Highlands scheme). There are also some transfers from below the eastern escarpment. The economy of the Vaal River catchment, and much of South Africa, has been built on mining for over 130 years.

The Vaal River is probably the most developed and regulated river in Southern Africa – it has some 90 major man-made impoundments situated on the main stem and its tributaries. It has extensive water resource infrastructure and is linked by substantial transfer systems to other water resource systems. There are also significant transfers out of the Upper Vaal catchment through the distribution system of Rand Water to the Crocodile West and Marico catchments. System supply reaches most of Gauteng, Eskom's power stations and Sasol's plants on the eastern Highveld, the North West and Free State Goldfields, the North West platinum and chrome mines, iron and manganese mines in the Northern Cape, Kimberley, several small towns along the main course of the river, as well as several large irrigation schemes.

The significant development within the system includes both formal and informal urbanisation, industrial growth, agricultural activities and widespread mining activities. This development has led to deterioration in the water quality of the water resources in the system, requiring that management interventions are sought to ensure that water of acceptable quality is available to all users in the system, especially as land use activities continue to grow and intensify. Salinisation and eutrophication of the water resources in the Vaal River System appear to be the two major water quality problems being experienced. A key consequence of the mining over the century has been the growing problem of acid mine drainage (AMD). This does pose a future risk to the water quality of the Vaal River. A current operating rule in place in the system to manage water quality are dilution releases that are made from Vaal Dam to maintain the salinity of the Vaal Barrage at a maximum of 600 mg/l.

Land use in the Upper Vaal is characterised by expansive urban, mining and industrial areas stretching between the Grootdraai Dam and Mooi River catchments. Other development includes dry land agriculture. Several large towns located around the mining, industrial and agricultural development areas. The impact of mining on the economy of this area is significant. The continued importance of the mining sector can be attributed to the coalfields in the northern parts and gold mining in the north-west of the Upper Vaal catchment area. Although the gold ore has been depleted in parts of the catchment, the largest unmined gold reserves in South Africa occur near Westonaria, with significant deposits also found at Carletonville and Randfontein. The increasing depth of gold mining, however, limits the economic viability of mining lower grade ore.

Products of the mining industry in the Upper Vaal include precious metals (gold, uranium) base metals, semi-precious stones, industrial minerals and coal. Coal mining occurs in the Bethal to Secunda area. Gold mining also occurs in the upper Waterval catchment (Secunda area). The area downstream of the Vaal Dam is also characterised by a large number of mining activities ranging from gold mining to quarrying. These mining activities occur in the Klipspruit, Suikerbosrand, Vaal Dam to Vaal Barrage and Mooi sub-catchments. Large gold mining operations are also located on the West Rand. Operating collieries are located in the Vereeniging-Vanderbijlpark-Sasolburg area adjacent to the Vaal River.

The present character of land use in the Middle Vaal has been shaped by the discovery of diamonds in the north-western part of the catchment in the vicinity of Klerksdorp, Welkom and Virginia, with these areas now being dominated by gold mining. Current land use in the Middle Vaal is characterised by extensive dry land cultivation in the central parts of the catchment. Irrigation is practiced downstream of dams and along the main tributaries and at locations along the Vaal River. Numerous inactive mines are found in the north and west of the catchment, many of which were small diamond claims. The Middle Vaal is also characterised by a large number of gold mines (Free State Goldfields area and North West Goldfields area) especially in the KOSH area (Klerksdorp-Orkney-Stilfontein-Hartbeesfontein). There are several diamond mine activities (varying from small-scale one-man operations to larger scale operations). The Klerksdorp goldfield, constituting seven producing mines, is part of the larger Witwatersrand goldfield. It is an important contributor to the South African gold, uranium and pyrite (sulphur) production. These mines still have a substantial reserve base of gold-bearing reef which, at the current rate of exploitation, is likely to last for many years to come. The economy of the Middle Vaal is dominated by the mining sector, particularly gold mining. The MidVaal Water Company (Stilfontein) is the main supplier of bulk water to urban areas in the North West Goldfields and Sedibeng Water (Bothaville) is the main supplier of bulk water in the Free State Goldfields.

The Lower Vaal, due to the arid climate is characterised by extensive livestock farming and large-scale dry land cultivation in the north eastern part of the catchment. Intensive irrigation is practised at Vaalharts, as well as at locations along the Vaal River. Kimberley is the largest urban centre in the catchment. Several towns as well as scattered rural settlements are found mainly in the central and eastern part of the Lower Vaal. Mining activities in the Lower Vaal area include diamonds, iron ore, manganese, lead, zinc and other minerals such as limestone and asbestos. The area includes the Kalahari manganese field. The Sishen Mine, south-west of Kuruman, currently is the major supplier of iron ore in the country. Relatively little of the mining production is beneficiated locally. Diamonds are mined from kimberlite fissures north of Swartruggens and from alluvial materials in the Lichtenburg-Ventersdorp and Schweizer Reneke areas, as well as along the Vaal River. Limestone and dolomite are produced from two quarries in the Lichtenburg District. The manganese and iron mines in the Lower Vaal have significant water requirements. These are all situated in the dry north-west section of the catchment and are supplied with water from the Vaal River System by the Vaal Gamagara Transfer Scheme.

The water balance reconciliation for the system does require that five core interventions to be implemented to ensure that sufficient water is available to users in the short term. The interventions include eradication of the extensive unlawful water use, implementation of water conservation and water demand management measures (15% reduction by all municipalities in Gauteng), re-use of water, implementation of an integrated water quality management strategy and implementation of Phase 2 of the Lesotho Highlands Water Project.

The management of mining water in the Upper Vaal is crucial to the management of water quality both in the short term to alleviate the current salt loads being released and long term to manage the impacts of mine closure and mine decants. Of further concern is the final decant points within the system once all the mines within this area close and pumping ceases. This is unknown at this stage but have future ramifications for all surrounding catchments. The water quality of the Grootdraai Dam is currently acceptable, however, there are a number of operational and defunct coal mines in the catchment which will have a significant impact if not appropriately managed. A deterioration in the pristine water quality of Grootdraai Dam has been recorded over recent years. This has implications for the strategic uses that rely on this water.

The mining areas of the Upper Vaal (which include the Eastern, Western and Central basins) have been identified by the inter-ministerial task group on mine water management in the Witwatersrand Goldfields formed in 2010, as areas requiring AMD intervention and management as a matter of urgency. The Upper Vaal was identified as a high priority catchment in terms of mining related water impacts. In 2011 emergency works were undertaken by the Trans-Caledon Tunnel Authority to protect the respective Environmental Critical Levels (ECLs) in the Eastern and Central Basins and to lower the underground mine water levels in the Western Basin; and to neutralise and remove the heavy metals from the pumped underground mine water prior to it being released to surface water resources. Considered as ‘short-term’ interventions, these are currently being implemented to manage the excess water and water quality until the long-term AMD solutions are selected for implementation. A feasibility study was undertaken in 2013 by the DWS for the long-term solution where a number of options were assessed.

The impacts from the gold mining activities within the Middle Vaal catchment on the quality of the groundwater and the interaction with the Vaal River has over the past two decades become a major concern. Localised dewatering became an issue at Stilfontein Gold Mine in the 1960s and to date the largest volumes are abstracted at Stilfontein Gold Mine’s Margaret Shaft. Although Stilfontein’s underground operations has ceased for more than a decade ago, pumping at Margaret Shaft continues daily for the safety of the downstream mines. The water is utilized by a number of users and any excess is discharged to the Koekemoerspruit. The mine water that is dewatered from Margaret shaft has been identified for re-use by the mines for the re-working of old slimes dams. This project has been identified to go on for at least the next 15 to 20 years. Following this, if all underground mining ceases only then is it foreseen that the dolomites will fill up and decant. The establishment of a Water Company has been proposed to treat and use the water in order to reduce and minimise the impact on the water resources and surrounding catchment.

If the salt loading on the Vaal River System associated with the discharges of AMD from mines and sewage effluent are not eliminated or suitably reduced, excessive dilution-releases from the Vaal Dam will be required to achieve the Resource Water Quality Objectives in the Vaal Barrage and downstream river. This will result in unusable surpluses developing in the Lower Vaal River, potentially externalising the cost of pollution to the Lower Orange River. Should the AMD issue, and specifically the increasing salt loading caused in the Vaal River System, not be addressed appropriately, the acceptable levels of assurance of water supply may be threatened in the up-coming years.

ORANGE WMA

The Orange Water Management Area comprises the Upper Orange and Lower Orange catchment. This core area forms part of the Orange-Senqu River Basin, which straddles four International Basin States with the Senqu River originating in the highlands of Lesotho, Botswana in the north eastern part of the Basin, the Fish River in Namibia and the largest area situated in South Africa. The Orange River is an international resource shared by these four countries.

The Orange River, the largest river in South Africa, has its origin in the high lying areas of Lesotho. The river drains a total catchment area of about 1 million km^2, runs generally in a westerly direction and finally discharges into the Atlantic Ocean at Alexander Bay. The Caledon River, forming the north-western boundary of Lesotho with the South Africa, is the first major tributary of the Orange River. The Caledon and the Orange (called the Senqu River in Lesotho) rivers have their confluence in the upper reaches of the Gariep Dam.

Other major tributaries into the Orange River are the Kraai River draining from the North Eastern Cape; the Vaal River joining the Orange River at Douglas; the Ongers and Sak Rivers draining from the northern parts of the Karoo; the Molopo and Nossob Rivers in Namibia, Botswana and the Northern Cape Province which have not contributed to the Orange River in recorded history as the stream bed is impeded by sand dunes and the Fish River draining the southern part of Namibia.

The main storage dams in the Orange River are Gariep and Vanderkloof, Welbedacht Dam in the Caledon River, Rustfontein, Mockes, and Krugersdrift Dams in the Modder River with the Tierpoort and Kalkfontein Dams in the Riet River. The Gariep Dam, Vanderkloof Dam, Orange-Fish Tunnel, Orange Vaal transfer canal and Orange-Riet Canal system are all part of the Orange River Project.

The Orange River is of critical importance to South Africa. The Vaal River System is augmented from the upper Orange (Senqu) by the Lesotho Highlands Water Project and supplies the economic heartland of South Arica. It also supplies thermal power stations on the Highveld, irrigation schemes covering large areas along the Vaal, middle and lower Orange Rivers. Some 15 million people are dependent on secure water supplies from this basin.

Land use in the Upper Orange area of the WMA is mainly under natural vegetation with livestock farming as main economic activity. Extensive areas under dry land cultivation, mostly for the production of grains, are found in the north-eastern parts of the Upper Orange. The Modder Riet catchment is dominated by agricultural activities, with limited mining, and a few urban centres. Ficksburg is famous for the cherry orchards in the region. Large areas under irrigation for the growing of grain and fodder crops have been developed along the main rivers, mostly downstream of irrigation dams. Mangaung (Bloemfontein), Botshabelo and Thaba 'Nchu represent the main urban and industrial developments in the catchment. Two large hydropower stations were constructed at Gariep and Vanderkloof Dams. Mining activities have significantly declined and currently mainly relate to salt works and small diamond mining operations. The most significant mine is De Beers Koffiefontein. Discharges from mines are not significant in this WMA. The economy of the Upper Orange WMA is not influenced by the mining sector (<1,0% of GGP), but urban centres such as Koffiefontein rely on the presence of mines for their existence (DWA, 2004). Approximately 5% of the GDP of South Africa originates from the Upper Orange WMA (DWAF, 2003).

The Lower Orange includes the stretch of Orange River between the Orange-Vaal confluence and Alexander Bay. The Orange River, which forms a green strip in an otherwise arid but beautiful landscape, also forms the border between South Africa and Namibia. Other tributaries are the Ongers and Hartebeest rivers from the south, and the Molopo River and Fish River (Namibia) from the north. There are a number of highly intermittent water courses along the coast which drain directly to the ocean. The Lower Orange catchment is the largest, but also the driest and most sparsely populated catchment in South Africa. Mining operations in the Lower Orange include underground and surface mines as well as quarries. Products of the mining industry in the Lower Orange are predominantly alluvial diamonds, copper and salt. Base metals are also mined. There are a few quarries providing stone aggregate and gravel. O'Kiep Copper Mines, Black Mountain Mines (lead, zinc and copper), Alexkor Mine (alluvial diamonds), Kleinzee Diamond Mine and Hondeklipbaai Mine (alluvial diamonds) are the major mines in the catchment that contribute to the significantly on the economy. Wastewater from the mines is evaporated through evaporation ponds and is not returned directly into the river systems. As the mines are not dewatered the groundwater movement that produces pollution plumes in the dry riverbeds need to be investigated further.

Minerals and water from the Orange River are the key elements for economic development in the region, and still remain so. Irrigation is by far the dominant water use sector in the Lower Orange, representing 94% of the total requirements for water. The importance of the agriculture sector is attributable to the climate which is particularly suitable for the growing of some high value crops, together with the availability of water along the Orange River.

Both the flow regime and water quality in the Orange River has been severely impacted upon by extensive upstream developments. Salinity in the Orange River has increased due to the transfer of good quality water away from the Orange River (in Lesotho and the Upper Orange WMA) and as a result of saline irrigation return flows along the Orange River and its main tributaries. Poor quality water from the Vaal River, which contains a high proportion of irrigation return flows, mining drainage as well as treated urban effluent, also periodically enters the Orange River.

Present water demands on the Orange System are broadly in balance with supply, however, growth in water demand over the next 30 years will cause shortages over time (DWS, 2015). Any further demand will have to be met either by increasing the supply (by building more storage) or improving the management of existing uses.

Water required to supply the current and future social and economic activities of the Orange WMA as well as supporting the transfer to the Vaal River system, will have to come from within the Orange/Senqu basin. Water reconciliation measures that have identified to maintain a balance between water requirements and availability to 2050 include groundwater development for domestic supply to many small towns; shared utilisation of the Lesotho Highlands Water Project Phase II between the Vaal and the Orange systems; implementation of WC/WDM measures in the domestic and irrigation water use sectors; development of mechanism to transfer savings achieved through water use efficiency in the agricultural sector to be made available to other users; limiting of operational losses from the Vaal River spillages; optimal utilisation of Van der Kloof Dam's storage capacity; creating additional yield by raising Gariep dam and investigating further management measures, such as lowering the assurances of supply, eliminating unlawful water use and eradicating invasive alien plants.

MZIMVUBU-TSITSIKAMMA WMA

The Mzimvubu-Tsitsikamma WMA encompasses much of the Eastern Cape Province and includes a number of very large and vastly different catchments, from the sub-tropical in the north east and the arid Karoo in the west. The WMA comprises the Mzimbuvu, Mtata, Mbashe, Groot Kei, Nahoon, Buffalo, Keiskamma, Boesmans River, Great Fish, Sundays, Kowie, Kromme, Groot, Gamtoos and Tsitsikamma catchment areas. All these river systems drain to the Indian Ocean. The climate and temperature variations are closely related to elevation and proximity to the coast. The area experiences a mild, temperate climate along the coast to more extreme conditions inland with most rainfall occurring during the summer months.

The Mzimvubu River (the largest undeveloped river in South Africa) flows through deep gorges across the coastal plain before discharging into the Indian Ocean at Port St Johns. The Mzimvubu River catchment area is one of the poorest and least developed parts of South Africa. The Amatola coastal catchments feature the main rivers of the Buffalo, Keiskamma and Nahoon that drain in a south-easterly direction into the Indian Ocean near East London. There is a potential of further dam development within the catchment. The Great Kei catchment drains the northern slopes of the Amatola mountain range and the southern slopes of the Stormberg / Drakensberg range with the Great Kei River exiting into the Indian Ocean at Kei Mouth north of East London. The catchments of the Great Fish and Sundays Rivers extend from the watershed of the Orange River system to the shoreline of the east coast of South Africa. The Fish and Sundays catchments are very dry. The Krom River drains a narrow valley between the Sundays Mountains to the interior and the Tsitsikamma Mountains towards the coast. The Gamtoos River catchment includes the Groot River and Kouga River as major tributaries. The Groot River catchment lies in the Karoo and the Kouga River rises in the Baviaanskloof Valley. These rivers join to form the Gamtoos River which drains the western slopes of the Elandsberg mountain range to the Indian Ocean.

Urban areas within the WMA include are Nelson Mandela Bay (Port Elizabeth, Uitenhage and Despatch) and Buffalo City, and the towns of Grahamstown, Craddock and Queenstown. The large percentage of the population of the area is situated in rural areas where their incomes are directly linked to the agricultural sector, which is mainly subsistence. Extensive irrigation agriculture has developed alongside the Fish and Sundays Rivers. Other main economic activities include tourism and commercial forestry activities, as well as manufacturing – vehicle manufacturing being the dominant industry in the Buffalo City Municipal Area. The Mzimvubu to Keiskamma area (Buffalo city and surrounds) are supplied with water through the Amatole Bulk Water Supply system, while the western catchment area (Fish and Sundays area are supplied through the Algoa Water Supply system. The Algoa system meets the needs of about 1 million people and generates approximate 2.5% of the national GDP (DWS, 2010). The only area expected to experience significant growth in the future are the Buffalo City Municipal and the Nelson Mandela Bay Municipal areas where employment opportunities will attract people from the smaller urban centres and rural areas. Mining activity in the WMA is very limited with the Molteno-Indwe Coalfield and isolated deposits of phosphate, nickel, lead, titanium and zirconium.

The Mzimvubu to Keiskamma area is a water rich area in which the water resources have not been fully developed. Small hydro-electric developments exist in the area, and inter-basin water transfer occurs between the Kei and the Mbashe catchments. The water requirements of the area are much less than the potential yield and this situation is likely to continue. There are few areas where water requirements exceed the yield of the local water resources and interventions are needed. Feasibility studies are underway for future dams. These areas include additional water supply for Queenstown (possibly from Xonxa Dam), for Buffalo City Municipality, Albany Coast and towns in the Bushman's River catchment. Key interventions include WC/WDM, re-use of wastewater, enhancement of dam yield through return flows, water quality improvement and institutional arrangements and management.

Future water resource development and interventions are also required in the Nelson Mandela Metropolitan Municipality to support growth in water requirements. The water requirements of the Great Fish and Sundays catchments are being met with water transferred from the Orange River. Measures to ensure anticipated growth in water requirements include, the implementation of urban WCWDM and re-use of water, increased operational efficiency of existing Kouga/Lourie scheme, desalination and additional development. Groundwater development and improved management is required to meet the water requirements and support water services in many areas in the WMA.

BREEDE-GOURITZ WMA

The Breede-Gouritz WMA is bounded by the Indian Ocean to the south, the Berg-Olifants WMA to the west, the Orange WMA to the north and the Mzimvubu-Tsitsikama WMA to the east. It falls largely within the Western Cape Province with small portions of the upper catchment of the Olifants River falling in the Eastern Cape Province and tiny portions of the upper catchments of the Gamka and Groot Rivers within the Northern Cape Province.

The Breede Gouritz WMA comprises the Breede, Overberg, the Karoo and Klein Karoo and Outeniqua Coastal Area (Stilbaai to Plettenberg Bay) catchments. There are two large rivers in the catchment *viz*. the Breede and the Gouritz. Other major rivers include the Riviersonderend, Sout, Bot, Palmiet, Gouritz, Olifants, Kamanassie, Gamka, Buffels, Touws, Goukou and Duiwenhoks. Much of the WMA is rural in nature.

The Breede Overberg catchment is characterized by mountain ranges, the Breede River valley and the hills of the Overberg in the south. The Breede River is currently intensively utilised, with two large dams *viz*. the Brandvlei and Theewaterskloof dams. There also a number of medium to small dams and a large number of farm dams. The area includes the major towns of Worcester and Ceres, and a number of smaller towns which amongst others include Grabouw, De Doorns, Robertson, Swellendam, Montagu, Caledon, Hermanus and Gansbaai. The land use is dominated by commercial agriculture in the Breede and Overberg areas. Irrigated agriculture (wine and table grapes, dairy and deciduous fruit), livestock farming, dry land agriculture (wheat and canola) and associated activities (packaging and processing) and the primary economic activities in the area. The catchment area produces 70% of South Africa’s table grapes, apples and fynbos for export. Tourism and residential development along the coast are also key economic drivers in the region. Groundwater use in the area is important to supply many towns and farms in the area. Intensive irrigation in the Breede catchment is causing increased salinisation of the rivers in the area and impacting on water quality. The Palmiet River catchment is intensively farmed. The lower reaches of the Palmiet River are protected as part of the Kogelberg Biodiversity Reserve requiring the ecological condition to be maintained. Water is transferred from the Breede catchment from the Theewaterskloof Dam to the Western Cape Water Supply System.

Within the Karoo to Klein Karoo catchment, the area is vast and dry. Some water does flows through from the Swartberg mountain range. The area includes the Beaufort West, as the major town in the north west of the area, which is largely reliant on groundwater. Other smaller towns include Oudtshoorn and De Rust within the Gouritz catchment area, which also include the Dwyka, Groot, Gamka and Olifants tributaries. The Gouritz River is the main river, contributing a large proportion of the surface flow in the catchment area. The Gouritz catchment area has good arable land available, however, irrigation is limited due to the low and variable rainfall. Existing resources have been over allocated with no opportunity for further dam development. The Klein Karoo is water stressed, as there is no additional surface water development available to support the growing needs of Oudtshoorn, Dysseldorp and surrounding areas. Potential exists to exploit groundwater to augment water supply. Elevated salinity occurs naturally within the inland catchments of the Karoo and Klein Karoo due to the geology of the area, which poses a problem for groundwater exploitation. Impacts on water quality have been observed due to land-based activities in the more populated areas.

The Outeniqua coastal catchment area (Stilbaai to Outeniqua) is ecologically sensitive, with many short steep rivers of high ecological importance. There are a number of National Parks and conservation areas in the catchment. This is a major growth area, popular as a retirement location and year-round tourist destination. The area includes small to medium sized dams (Wolwedans and Garden Route Dams). Surface water resources have been almost fully developed and alternative supplies are required.

In the Karoo to Klein Karoo and Outeniqua coastal areas the agricultural sector provides the primary economic driver of the region (a large variety of crops, livestock and fruit). The fish and shellfish industry, tourism and the ostrich industry are also significant for the economy of the coastal region. Land use is dominated by irrigation and afforestation activities. Mining activity in the WMA is very limited, with a few isolated deposits of phosphate, limestone and salt.

In terms of surface water management, WMA is managed in terms of ten hydrological sub-areas, *viz*. upper Breede, lower Breede, Riviersonderend, Overberg West and the Overberg East; Gamka, Groot, Olifants, Gouritz and Coastal sub-areas. The reliability of the hydrology in many parts of the WMA is, however, not good and needs to be improved along with related streamflow reduction activities (BGCMS, 2018).

Much of the future growth in water requirements in the WMA is driven by the increase in the urban, domestic, industrial water requirement sectors. The WMA is in water stress with many areas presenting a water deficit, with a few exceptions.

Prioritised actions to address water system deficits include validation and verification of water use; implementation of WCWDM, implementation and monitoring of operating rules, desalination options for the coastal towns, evaluation of water balances of irrigation schemes to determine their water deficit situations and feasibility of groundwater development in relevant areas. The impact of the implementation of ecological water requirements is also required to understand the water balance of the sub-systems in the WMA.

THE BERG OLIFANTS WMA

The Berg Olifants WMA lies within the Western Cape and Northern Cape Provinces and includes the Berg and Olifants catchment areas. The major rivers in the WMA are the Berg, Diep, Steenbras, Olifants, Doorn, Krom, Sand and Sout. The WMA includes Cape Town the second most populous metropolitan area in South Africa. The economy of the WMA is closely linked to the economic powerhouse of the City of Cape Town Metropolitan City (WCG Provincial Treasury, 2013). The Cape Town Metro contributes close to three-quarters of the real value-add generated in the Western Cape Province and is an important contributor to the economic growth in WMA. There are several large towns in the WMA with quite diverse economies which includes tourism, irrigation and dryland agriculture, wine-making, canning, food processing, manufacturing, fisheries, commercial forestry, financial services, information technology and communications, mining, nuclear power generation, hydropower generation and port operations.

Natural vegetation comprises large areas of Cape Fynbos, which represents one of the unique floral kingdoms of the world and is a recognised World Heritage Site. A number of conservation and heritage sites are found in the WMA. Large spatial variations in rainfall, water availability, level and nature of economic development, population density as well as potential for development for growth exists in the WMA.

The Berg River catchment comprises the Upper Berg area which includes the Berg River catchment down to Misverstand Weir; the Lower Berg area, which includes the downstream reaches of the Berg River together with the endoreic areas along the west coast including the Diep River catchment and the Greater Cape Town area, the southern portion of the WMA with a number of smaller river catchments.

The Olifants and Doring River catchment comprises the well-watered valleys of the Olifants River catchment, the arid Doring River catchment and the highly developed Sandveld area forming the western coastal boundary.

The diversified economy of the Berg River catchment is dominated by industrial and other activities in the Cape Town Metropolitan area. Other significant economic sectors include irrigated agriculture, namely wine production, table grapes and deciduous fruit exports, and tourism. The Olifants area is dominated by extensive commercial agriculture (irrigated citrus, deciduous fruits, grapes and potatoes), but also includes tourism, livestock farming, some industries related to processing and packaging and limited forestry.

Mining activity in the WMA is very limited. The only major mine is the Namakwa Sands heavy minerals mine located to the north-west of the WMA. There are also several granite quarrying operations in the vicinities of Vredendal and Vanrhynsdorp and the Vredendal goassanous iron deposit. Dredging for marine diamonds occurs offshore. There are smaller phosphate and titanium mining operations in the vicinity of Langebaan.

The WCWSS comprises of several dams, mostly located in the upper regions of the Berg River and Breede River catchments. The main storage dams are the Theewaterskloof, Voëlvlei, Berg River, Wemmershoek and the Upper and Lower Steenbras dams (DWS, 2010). The system serves more than 3.2 million people and supplies raw water to the City of Cape Town and certain Overberg, Boland, West Coast (including Saldanha) and Swartland towns, as well as to agricultural users downstream along the Berg, Eerste and Riviersonderend rivers. The area generates approximately 14% of the national GDP.

The water resources of the WMA are fully developed and investigations are underway to assess options to augment water supply. The system was identified as a water stressed area in 2013 requiring intervention, by immediate implementation of WCWDM measures. Between 2015 and 2017 the southern Western Cape region experienced three of its lowest rainfall years on record. This led to the progressive depletion of water supply dams and by the summer of 2017/18 there was a real danger that, without drastic reductions in water use the region, and especially the city of Cape Town, would run out of water. Severe water shortages were experienced that led to restrictions of water use within the WCWSS. The situation in the catchment although somewhat improved is still in a water stressed state. The reliable yield of the South Western Cape water system has, until now, been calculated under the assumption of a stationary climate. This will in future have to change to account for the changes in climate.

Options to augment water supply include intensified WCWDM, desalination, infrastructure development (Voëlvlei Augmentation Scheme and Berg Water Transfer Scheme), re-use of water and groundwater exploitation.

CONCLUSION

Based on the WMA perspectives provided above, it is evident that water deficits are a reality in most catchments throughout South Africa. At a national level, as part of water resources planning in reconciling water demands with water supply throughout the various catchments in South Africa, intervention scenarios in particular for the large water supply systems and metropolitan areas where more than only one intervention option is required, comprise the introduction over time of various combinations of reconciliation options, which can be divided into two main categories:

- Reconciliation Options that reduce water requirements.
- Reconciliation Options that increase the water supply.

The implementation of WCWDM activities remains one of the more cost-effective intervention options to improve the water balances of water supply systems. WC/WDM strategies are now required by Government policy, as a prerequisite to considering infrastructure-related developments to improve the water supply within sub-systems. WC/WDM is therefore included as the first intervention option to be implemented in all the reconciliation strategies, for the different water supply systems.

Using less through improved efficiencies and losing less between source and user is critical. Implementation of WCWDM measures is urgent and unavoidable and is necessary to avoid serious and imminent risks of water shortages in many catchment areas.

Re-use of water is also an important and growing strategy in addressing water shortages, specifically an opportunity to address the decanting of mine-polluted groundwater into surface water resources. This of specific relevance in the Vaal and Olifants WMAs. Additional serious threats to water quality also include deterioration due to agricultural, mining, industrial and settlement pollution.

It is evident that securing water supplies for the diverse catchment areas throughout South Africa, a range of measures are required to meet the water supply needs of a growing economy and a mixed range of water users. Adaptable strategies and interventions from the status quo are required going forward, where water will be viewed as a commodity. The future of mining as a user, also needs to adapt and adopt a responsible and proactive view in terms of how water is valued and utilised as a resource. Implementation of best practices that minimise and/or re-use water and improve water use efficiencies within the mine fence is one of the first steps towards conserving this precious commodity.

APPENDIX 5 – WATER QUALITY CONSIDERATIONS

WC/WDM is a specifically a water quantity aspect looking at reducing the overall water quantity/volume requirement for a mine. WC/WDM cannot, however, be implemented without water quality considerations. Quality of water is key to water recycling and re-use. According to the SWAF, water will be categorised as shown in Table 30.

The water quality categories are intended to provide a broad indication of the quality of water and the ease with which it can be used/reused within the mining industry. In terms of the WC/WDM process, the categorisation assists with distinguishing between water that can be used as is with no treatment (category 1), water that requires minimal treatment such as neutralisation and suspended solid removal before re-use (Category 2) and water that requires extensive treatment such as desalination before re-use (Category 3). It is important to take the conservative approach where two or more water quality parameters exceed the values as per Table 30. The water stream must be accorded the higher water quality category.

A fit for use approach is to be adopted when considering recycling and treatment requirements. The mine should ensure the adherence to water quality standards/requirements for all water users that aims to provide all users with the worst possible quality water that does not affect the process performance or cause corrosion / scaling problems. The categorisation was done to force people to think more about clean and dirty water separation, reusing the cleaner water instead of using more “new” water! The worst category could be treated and re-used – at a reduced plant size and cost, making WCWDM more attractive.

Table 30: Water quality categories to assist with the determination of what treatment is required

Parameter	**Units**	**CATEGORY 1 Water that can be re-used without treatment**	**CATEGORY 2 Water that can be re-used with simple treatment**	**CATEGORY 3 Water that may require extensive and costly treatment**
Physical				
Conductivity	mS/m	< 5300	300-700	> 700
Ph		5.5-8.5	< 5.5 or > 8.5	Ns
Suspended solids	mg/l	< 50	> 50	ns
Chemical	mg/l			
Alkalinity	mg/l	10-200	< 10 or > 200	10-200
TDS	mg/l	< 2000	2000-5000	> 5000
Calcium	mg/l	< 250	250-500	> 500
Magnesium	mg/l	< 200	200-400	> 400
Sodium	mg/l	< 200	200-400	> 400
Potassium	mg/l	< 200	200-400	> 400
Sulphate	mg/l	< 1000	1000-2000	> 2000
Chloride	mg/l	< 200	200-500	> 500
Langlier Saturation Index (LSI)		0-0.5	< 0 or > 0.5	ns

WATER QUALITY DRIVERS

The following are drivers affecting water quality in the mining industry:

- Weathering / oxidation of natural minerals associated with ore bodies.
- Many sulphide-based metals containing ore bodies
    - Sulphide naturally oxidises to form sulphuric acid.
    - Pyrite is a common mineral associated with coal, gold and metals geological bodies / ores associated with the following reaction:
      $4FeS_2 + 15O_2 + 14H_2O \rightarrow 4Fe(OH)_3 + 8SO_4^{2-} + 16H^+$
    - Release of sulphuric acid dissolves many constituents, hence releasing further contaminants.
- Application and use of chemicals in mines / metallurgical plants

Potential constituents of concern from mining

Typically, water contaminated in a mining process will contain the following constituents of concern (COCs):

- Salinity – Ca, Mg, Na, SO_4, Cl, F, TDS
- Turbidity, suspended solids
- Acidity / linked to metals – Fe, Al, Mn, Cu, Zn
- Nitrogen p NH_3-N, NO_3-N
- Other quality constituents

Available information on leach tests and water samples is most common for the coal, gold and PGE mining resources. Therefore, this section will focus on these commodities. Within the gathered information, it is clear that potential ARD or acidic leaching from waste rock dumps, tailings and other residue deposits is highly dependent on the mined ore body and is especially dependent on the presence of sulphur and neutralising material such as carbonates within the surrounding rock.

Coal

Coal mines are spread around the country across a number of Water Management Areas (WMAs), and within those WMAs, they are spread across a number of coalfields. This determines the extent of potential constituents of concern (PCOCs) from discard material and decant.

Coal in the Limpopo WMA is acid generating. However, the overburden has significant neutralising potential, which can counter-balance this. PCOCs include SO4, Fe, Cu, Zn, Al, Ni, Mn, among others. Coal in the Olifants catchment is generally acid generating, and PCOCs include pH, TDS, SO4, Mn, among others.

The Inkomati-Usuthu WMA showed various findings depending on the mined coalfield. The Ermelo coalfield tended to have an especially low outlook, with very limited buffering material combined with acid generating overburden, interburden and coal material. PCOCs include pH, TDS, SO4, Fe, Mn, Ca, among others. Calcium was often seen which suggests leaching out of neutralising material in the underground rock in an attempt to combat the acidic water. In one case dolerite was found in the overburden which could provide some neutralisation. However, underground water from this mine was also found to have a low pH with high levels of Fe and SO4. Other coalfields within the Inkomati-Usuthu WMA showed coal that was not potentially acid generating with mine pits producing alkaline water, and in other cases very low levels of sulphur was present in the rock, with a low risk of acid rock drainage (ARD).

The Pongola-Mtamvuma WMA showed underground rocks with high variability in neutralisation potential. In general, coal and discard were acid generating, but the risk of ARD ranged from low to high depending on the mine. PCOCs include TDS, SO4, Na, Mg, Al, Fe, Mn, Ca, among others. The Mzimvubu Tsitsikama WMA showed uncertain acid generating potential of the coal, and low acid generating potential of the roof and floor material. The risk of ARD was deemed to be low.

In terms of other processes that occur within a coal mine, the coal washing process is not a very slow process and therefore has limited opportunity to produce acidity. However, metals leaching can occur, and due to recycling, salinity of the water increases with the level of recycling. The extent of this salinity is therefore also dependent on water availability in the area, as areas with limited freshwater resources is likely to recycle coal wash water to a greater degree, and this water may eventually require treatment.

The need for clean water in a coal mine is low. Water is used for transportation and washing and only requires a neutral pH, with preferably low potential for scaling and organic slime formation. This means that coal mines can potentially make use of wastewater or partially treated water from other industries .... and should therefore use its own polluted water instead of abstracting raw water – thereby reducing raw water use.

Gold

In general, most gold mines are associated with acid generating rock and especially high acid generating tailings. However, in some cases carbonaceous material is present, which can reduce the rock to non-acid generating. PCOCs in the Olifants WMA include Mn, Co, As among other metals. PCOCs in the Inkomati-Usuthu WMA include SO4, As, and a range of other metals. PCOCs in the Vaal WMA include U, Ni and Mn. The PCOCs listed here are PCOCs found in common for various mines within each WMA.

Depending on the method of gold extraction, gold mining may also produce other constituents such as cyanide, radioactivity and other heavy metals. However, these constituents may potentially be removed in subsequent processes, and there is therefore no generalisation regarding these constituents, apart from saying that the technology exists to desalinate and re-use water being discharged, thereby reducing raw water abstraction and mine water discharges and its associated impacts.

Platinum Group Metals (PGMs)

Platinum group metals are mined within the Limpopo and Olifants WMAs. The Limpopo WMA is generally associated with low potential acid generation, especially within waste rock and tailings, due to low sulphur content in the rock. The ore itself may be acid generating or uncertain. PCOCs include TDS, sulphate, nitrate, chloride, As, Cr, Cu, Fe, Mn, among others. The Olifants catchment is associated with non-acid generating rock, with the potential for highly saline but neutral seepage from tailings. PCOCs include TDS, SO4, and various metals.

Other metals

Other available information included two iron ore mines, one in the Limpopo WMA and one in the Olifants WMA. Both of these mines were non-acid generating and unlikely to result in ARD. Furthermore, two zinc mines in the Orange WMA both had acid generating waste rock, ore and tailings, with PCOCs that included TDS, SO4, Cd, Cu, Fe, Mn, Pb and Zn. There is insufficient information to create a generalising statement regarding these commodities.

WATER TREATMENT OPTIONS FOR VARIOUS MINING COMMODITIES

Generic treatment technologies

The following are generic water treatment technologies that are/may be implemented to treat mine affected water for re-use:

- Precipitation technologies
    - Barium precipitation.
    - Ettringite precipitation
- Ion exchange technologies
- Membrane based (nano-filtration / reverse osmosis) technologies
    - Brine producing reverse osmosis technologies.
    - Non-brine producing nano-filtration technologies
- Passive technologies

Coal mining

In the coal mining industry, it is common for impacted water to have a high salinity and metals content, with or without a low pH. To treat this type of water to discharge or potable standards, it is generally necessary to have a lime dosing step for metals precipitation as a first step, which would also remove acidity and raise the pH. However, where pH is near-neutral, the dosing requirements for lime are far less, making the treatment process less expensive. The precipitation process is associated with clarification, thickening and solids handling, as well as sand filtration to remove residual solids from the treated water. Due to the high metals content, it is likely that the solids will be classified as a hazardous waste

Once metals have been removed, gypsum may co-precipitate if the sulphate concentration is high enough. Depending on the discharge water quality target, this may reduce the sulphate concentration sufficiently such that no further treatment is necessary. However, as in most cases, the sulphate target is relatively stringent. The saturation concentration of sulphate would therefore be too high, and requires membrane treatment, such as nano filtration or reverse osmosis. The brine can be de-supersaturated through lime addition, resulting in the precipitation of gypsum. The gypsum precipitate is non-hazardous and can be used offsite without incurring further costs. The remaining brine liquid can be mixed with the treated water to be discharged, in a treatment process that has a zero-liquid discharge. However, in the Pongola-Mtamvuma WMA and in some other individual cases across South Africa, the sodium concentration is above the discharge requirements. Sodium is usually removed using reverse osmosis. In this case, the brine liquid cannot be mixed back with the treated water, and results in a liquid waste stream which requires separate disposal.

Where the impacted water is to be re-used in the mine, it is necessary to neutralize any water that may have a low pH, to prevent metals leaching. This can be done with lime, which may result in unwanted gypsum precipitation, or an alternative alkaline source such as sodium hydroxide, which is more expensive. The disadvantage of gypsum precipitation is that it may result in scaling which could affect the process or damage equipment. The risks and benefits of each method should be weighed against each other. Where water has been re-used in the mine, it may be necessary to apply a form of filtration or sedimentation to prevent clogging of pipes and damaging of pumps and other equipment.

Gold mining

The water treatment process for underground water, including decants and seepage, are very similar to the coal mining case. This is because the constituents of concern are similar in terms of metals, acidity and salinity. However, there are some additional constituents which may occur in gold mining, such as uranium, radioactivity and nitrate. Uranium and radioactivity can be removed using ion exchange upstream of the lime precipitation step. Nitrate will be removed in a typical water treatment process without special additions of process units unless the levels of nitrate are excessively high. In this case, a specific concept design would need to be developed for the mine in question, as well as determining and potentially reducing the source of the nitrate contamination.

Water that has been affected by the gold processing plant is generally reused in the system. However, should this water need to be discharged, it would need to be treated to remove cyanide as well as metals and the other constituents previously mentioned. In this case cyanide can be removed using chlorine (either chlorine gas or hypochlorite), ion exchange or reverse osmosis. It is noted that water treated using chlorine cannot be reused in the gold process because it reduces the efficiency of gold recovery, and this method would therefore be used solely for water to be discharged. Ion exchange and reverse osmosis both produce a brine, which would be toxic and need to be disposed to a hazardous waste landfill site.

Platinum Group Metals

Ore and surrounding rock associated with PGM mining is generally less acidic than the rock associated with gold and coal mining. However, except for acidity, many of the other constituents of concern are similar, such as the metals, sulphate and nitrate. For this reason, the water treatment method is the same, albeit cheaper as the chemical dosing requirements are far less. This treatment process includes lime dosing with metals and gypsum precipitation, together with potential RO to remove residual nitrate and sulphate. The Limpopo WMA further has chloride as a constituent of concern, which would require reverse osmosis with associated brine handling and disposal.

Impacted water from transportation, crushing and milling processes can be reused for these purposes or for dust suppression. Excess water can be treated using sedimentation, filtration and potential metals precipitation with lime before discharge, depending on the level of contamination.

Impacted water from the flotation process is generally re-used. However, much of this water ends up in tailings which could emanate as seepage if the tailings facility is poorly designed or due to unforeseen circumstances. Furthermore, the water does become concentrated over time with contaminants from the ore which can affect the efficiency of the flotation process, which means that this water needs to be treated even if it is recycled. Treatment methods include adsorption on materials such as activated carbon, biological oxidation of organics, ion exchange to remove selected contaminants, and reverse osmosis.

Water used for cooling becomes more concentrated over time due to evaporation. This water needs to be bled and fresh clean water added to manage the salinity. The water that is bled can be used upstream in the crushing process. Alternatively, the water can be treated with reverse osmosis to reduce the need for fresh water. However, this produces a brine which would need to be treated or disposed of.

Other metals

Constituents of concern from various metals are expected to have many similarities, especially in terms of underground leachate or decant as well as water used for transportation and crushing. In these instances, the treatment method and water reuse options would be very similar. Water used for cooling would also need to be bled and used in applications that do not require a high-water quality or be treated with reverse osmosis. Where chemicals are added to the water, it would be necessary to conduct a study based on the specific constituents of concern found in that water.

COST OF WATER TREATMENT FOR VARIOUS SOURCES AND APPLICATIONS IN MINING

There can be a very large variation in water treatment costs depending on the extent of contamination of the water and the requirements of the treated water. Water with a high salinity and high monovalent concentration is most likely the most expensive to treat, especially if it is not just treated for reuse. Table 31 provides a range of costs for different water qualities and treatment standards.

It is assumed that the flow rate of water to be treated ranges between 1 and 5 ML/d. The higher the flow, the larger the capex cost and low the Opex cost per m^3 of water treated. Furthermore, the costs associated with a collection system and waste product (such as sludge or brine) treatment and disposal are not included.

Table 31: Comparison of treatment costs for different mine water treatment technologies

	Treatment to discharge	Treatment for reuse in coal washing or transportation	Water re-use in same application where contamination occurred
Low pH impacted groundwater with high salinity and monovalent concentration	Highest cost Capex: R24 million - R94 million Opex: R8.50 - R19/m^3 treated Provision for sludge and brine treatment/disposal	Medium cost Capex: R12 million - R40 million Opex: R4-R7/m^3 treated Provision for sludge disposal	N/A
Near neutral impacted groundwater with high salinity	High cost Capex: R17 million - R60 million Opex: R8 - R14/m^3 treated Potential provision for sludge disposal	Low-medium cost Capex: R3 million - R10 million Opex: R2 - R4.50/m^3 treated Potential provision for sludge disposal	N/A
Near neutral impacted groundwater with low salinity	Low cost Capex: R0 - R2 million Opex: R0.40 - R2.50/m^3 treated (includes analytical and associated costs)	Low cost Capex: near R0 Opex: near R0	N/A
Impacted water used in coal washing and transportation	Medium cost Capex: R7 million - R25 million Opex: R5 - R10/m^3 treated Potential provision for sludge disposal	Low cost Capex: Under R2 million Opex: Under R0.80/m^3 treated	Low cost Capex: Under R2 million Opex: Under R0.80/m^3 treated
Water used in concentration and flotation	Cost depends on specific contaminants and treatment methods chosen. Costs likely medium to high Potential provision for waste product treatment or disposal	Cost depends on specific contaminants and treatment methods chosen. Costs likely medium Potential provision for waste product treatment or disposal	Cost depends on specific contaminants and treatment methods chosen. Costs likely medium to low
Leachate (contaminated with cyanide)	Medium to very high depending on monovalent concentration. Capex: R10 - R90 million Opex: R4 - R15/m^3 treated Potential provision for sludge and brine disposal	Cost similar to treatment to discharge due to cyanide presence and low pH R10 - R80 million Opex: R4 - R15/m^3 treated Potential provision for sludge and brine disposal	Low cost Capex: near R0 Opex: near R0
Cooling water	Medium cost Capex: R10 million - R32 million Opex: R4 - R7.50 Potential provision for sludge and brine disposal	Low cost Capex: R2 million - R8 million Opex: R1.20 - R3.50 Potential provision for benign sludge disposal (gypsum and/or calcium carbonate)	Low-medium cost Capex: R3.5 million - R11 million Opex: R3 - R5.50 Potential for benign sludge and brine disposal

APPENDIX 6 – WC/WDM QUESTIONAIRE USED

Name:		**Company**:
Date:		**Phone-call/Email**:
Initial	**Question/Answer**	**Extra comments**
Q	Has there been any water conservation / water efficiency / water saving initiatives implemented on your mine?	
A		
Q	Do you have an operational water balance? What format is this water balance in? Is it regularly updated? What is it mainly used for?	
A		
Q	Have you utilized the water balance in conducting any water saving initiatives?	
A		
Q	What kind of water management reporting is done? Do you have any KPIs related to water management?	
A		
Q	How is this tracked? How do you improve on these KPIs?	

A		
Q	Has there been any changes done to the process plant or mining operation that has resulted in water savings?	
A		
Q	How is your water savings measured?	
A		
Q	Could you give me an estimate of the mines total water use?	
A		
Q	How do you manage your water intake?	
A		
Q	How many percent of the total water intake is reused/recycled?	
A		
Q	Does the mine have a water monitoring system (tracking of water consumption)?	
A		

Q	If water monitoring is through the use flow meters, are the flow meters regularly calibrated?	
A		
Q	Does the mine have a WC/WDM plan with clearly defined goals and objectives?	
A		
Q	What methodology was used in developing your WC/WDM plan?	
A		
Q	Do you believe the WC/ WDM the mine has in place are unique? (if yes, please elaborate)	
A		