GUIDELINE FOR THE DEVELOPMENT AND IMPLEMENTATION OF WATER CONSERVATION AND WATER DEMAND MANAGEMENT PLANS FOR THE MINING SECTOR

WC/WDM GUIDELINE

WATER IS LIFE - SANITATION IS DIGNITY

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FOREWORD

South Africa is a developing country that is water scarce, which emphasizes the necessity and importance to conserve and optimally utilize our scarce water resources. The implementation of WC/WDM programmes by all sectors is essential in meeting the national goals of basic water supply for all citizens of the Republic of South Africa. It is also important in ensuring economic efficiency and ensuring the sustainable use of water resources. Water Conservation and Demand Management is a fundamental step in promoting water use efficiency and is consistent with the National Water Act (Act 36 of 1998) which emphasizes efficient management of our water resources. This builds on the principles of the national water policy (DWA, 2007) which states that:

“Water resources shall be developed, apportioned and managed in such a manner as to enable all user sectors to gain equitible water. Conservation and other measures to manage demand shall be actively promoted as preferred option to achieve this objective”.

The current situation of widespread national water deficits creates an untenable scenario that requires all sectors (domestic, industry, agriculture and mining) be efficient and effective in the use of water. It is thus essential to improve the current level of water use efficiency and to implement Water Conservation and Water Demand Management (WC/WDM) measures as a vital aspect of norms and codes of good practice in water management by all sectors.

There are a number of factors that drive and influence future water demand, such as scarcity which leads to business risk, environmental and sustainability factors, price of water and economic policies. In this regard, mining together with the industrial sector, are seen as key sectors anticipated to drive economic growth. The mining sector is a significant user of water with an estimated demand of about 5% of the country’s available water according to the National Water Resources Strategy 2 and is currently expanding into new areas (particularly for coal and platinum) with projected increase in water demand. Many of the mines are located in water resource scarce catchments (e.g. the Lephalale and Steelpoort area in the Limpopo province) where the availability of water can become a significant business risk. Implementation of WC/WDM measures within the mining sector is required in order to minimise this risk.

The implementation of demand WC/WDM programmes will, amongst others, contribute to the protection of water resources by reducing the unnecessary abstraction of water and thereby promoting better management by users. It is thus appropriate, through the setting of national WC/WDM benchmarks, to create an enabling environment for all role players al)d stakeholders to appreciate the value of water and understand the importance of WC/WDM to ensure effective, efficient and sustainable water use.

MRS NP MOKONYANE
MINISTER OF WATER AND SANITATION

EXECUTIVE SUMMARY

The Department of Water and Sanitation in collaboration with the Chamber of mines has developed commodity-based national water use efficiency (WUE) benchmarks to guide the acceptable levels of water usage by the mining industry, and consequently to drive the improvement in water use efficiency through effective implementation of water conservation measures and strategies within the mining operations. This report provides a set of national water use efficiency benchmarks that are based on a very detailed analysis of the latest and most up-to-date available data on actual current specific water use data within the South African mining industry. This data was collected as part of an extensive site engagement process at 39 different mining operations that have been shown, through evaluation of production and water use data, to be truly representative of the national mining industry.

This data was then evaluated in order to develop as detailed a set of mine water balances as accurately as possible, given the limitations of the water balances reported by the mines. The data was further refined through a rigorous and objective methodology, in the manner described in this report, in order to identify national water use efficiency benchmarks that represent the current WC/WDM situation based on current practices within mines which are already reasonably advanced with their general water management practices.

A detailed generic water balance model was developed that was able to evaluate the effects of a number of critical variables (as listed in the variables matrix together with many more) on water use efficiency, both for individual variables, and probabilistically for the complete set of variables. This exercise resulted in the definition of an upper and lower range for the different key indicators that could then be applied to the national benchmarks (which are based on average values) to give a range that should be achievable by the majority of mines in South Africa.

The water balance model was also used to evaluate a number of generic water conservation measures in terms of the anticipated impact that they would have on water use efficiency benchmarks. This information can provide valuable inputs to mines when developing their own internal water use efficiency targets.

It was confirmed that the procedures set out in the WC/WDM Guideline (DWA, 2011) are valid and correct and should be used in the internal mine water use target setting process, together with this document and the WC/WDM Implementation Guideline developed as part of this project. It was also emphasized that the most critical component of a mine's WC/WDM plan is a detailed computerised water balance model that can be used to simulate proposed WC/WDM measures.

Finally, based on the literature review developed as part of Phase 1 of the project as well as subsequent additions of key literature published afterwards, it would appear that the setting of national water use benchmarks as has been done in this report is novel and has not been undertaken in other countries. The standard procedure is for mines to develop site-specific internal water use efficiency targets and to then report on the implementation thereof in a standardised manner.

FIGURES

TABLES

ABBREVIATIONS AND GLOSSARY

ABBREVIATIONS

AMD:	Acid Mine Drainage
BPG:	Best Practice Guideline (documents issued by the DWS)
CMA:	Catchment Management Agency
DWS:	Department of Water and Sanitation
EWULAAS:	Electronic Water Use License Application and Authorisation System
IWWMP:	Integrated Water and Waste Management Plan
KPI:	Key Performance Indicator
LoM:	Life of Mine
MCA:	Minerals Council of Australia
MPRDA:	Minerals and Petroleum Resources Development Act, 2002 (Act 28 of 2002)
NPV:	Net Present Value
NWA:	National Water Act, 1998 (Act 36 of 1998)
NWRS2:	National Water Reconciliation Strategy, Second Edition
ROM:	Run of mine
RWB:	Rand Water Board
RWD:	Return Water Dam
SG:	Specific Gravity
SWAF:	Standardised Water Accounting Framework (South African)
TSF:	Tailings Storage Facility
WAF:	Water Accounting Framework (Australian)
WC:	Water Conservation
WDM:	Water Demand Management
WETT:	Water Efficiency Target Tool
WU:	Water Use
WUE:	Water Use Effeciency

GLOSSARY

In assessing the definitions given below, it must be understood that the definitions as provided in the NWA and NWRS2 are primary.

Benchmarks: 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: 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.

Consumptive water use: 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 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: Any measure or initiative that will result in the reduction of the expected water use or water demand.

Efficient use of water: Water used for a specific purpose that is part of accepted and available best practices and benchmarks or water used for a purpose where benefit is derived from it (also referred to as water use efficiency).

Indicator: 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: 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.

Interstitial water: Water occurring in the small openings, spaces, and voids between particles of unconsolidated materials in that portion of the vadose water zone between the roof zone and the water table. The water is held in place by entrapment, ionic attraction, and capillary or adhesive forces, rather than from upward pressure components of saturation." - U.S. Geological Survey, 2006. Within the mining context, this typically refers to the water held by the material within a mine residue deposit and which cannot be recovered until such time as the residue deposit is decommissioned and the water table within the deposit drops, allowing at least partial recovery of the interstitial water. This is therefore water that cannot potentially be recycled/reused during the operational phase of the mine.

New water: 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 losses of water from the water circuit.

Percentage of wastewater not recycled or reused: This is one of the water use efficiency indicators for which the mine is required to set and meet targets. It is calculated as the volume of wastewater lost from the operations divided by the sum of the consumptive water use plus the recycled/reused water.

Regulation: A rule or directive made and implemented by an authority, which individuals or organizations are obliged to respect and comply with.

Residue deposit:	Residue deposits include any dump, tailings dams, slimes dams, ash dump, waste rock dump, in-pit deposit and any other heap, pile or accumulation of residue. (Government Notice 704 of 4 June 1999.)
Run of mine (ROM) ore:	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.
Standardised Water Accounting Framework (SWAF):	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.
Supply-side management:	Any measure or initiative that will increase the capacity of a water resource or water supply system to supply water to water user(s).
Targets:	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.
Total water use:	This is one of the water use efficiency indicators for which the mine is required to set and meet targets. It is calculated as the total volume of all “new” water used in any aspect of the mining operations and including all possible sources of water (water obtained from municipalities or other water utilities, ground water, surface water [rivers, wetlands, lakes and oceans], rain water, rainfall runoff, waste water from an external third party). Within the context of WC/WDM reporting, the sum of all water inputs is equal to the sum of all water outputs is equal to the total water use.
Total specific water use:	Also commonly known as “water intensity”, this is one of the water use efficiency indicators for which the mine is required to set and meet targets. It is calculated as the total water use divided by the run of mine (ROM) ore for a specified period.
Variables matrix:	A table or matrix of characteristics of a mine that may affect the degree of water water use efficiency that a mine can achieve.
Wastewater lost from the mine operations:	includes 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/in product and moisture retained within mine residues – interstitial water (reported as a volume – m^3/day or kl/day).
Water conservation:	The minimization of water loss or waste, the care and protection of water resources and the efficient and effective use of water.
Water demand:	The expected new water usage for a mine.
Water demand management:	The development, adaptation and implementation of a strategy, programme or a plan by a water institution or water consumer (such as a mine) to influence the water demand and the 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 Intensity:	Also referred to in this report as “Total Specific Water Use”. Water intensity is the water use per unit of economic activity. In the case of the mining sector, this is expressed as the amount of water used per unit of ore mined (ROM) and sent to the beneficiation plant.
Water reclamation:	The treatment of water to make it suitable for use by an identified user.

Water recycling: 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 Recycling Ratio: This is one of the water use efficiency indicators for which the mine is required to set and meet targets. It is calculated as the total volume of water recycled/reused by the mine divided by the sum of the total water use and recycled water (reported as a percentage).

Water reuse: 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 a 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: An annual on-line submission into the SWAF system whereby the mine reports on its updated water balance and progress towards meeting the targets committed to in the WC/WDM plan.

WC/WDM plan: 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 Standardised Water Accounting Framework (SWAF).

1. INTRODUCTION

The Department of Water & Sanitation (DWS) working in collaboration with the Chamber of Mines commissioned a project to undertake the "Setting of Water Conservation and Water Demand Management (WC/WDM) Targets for the Mining Sector". This project has been undertaken with the active participation and management involvement of both the DWS and a wide range of stakeholders from the mining sector. The primary deliverables that emanated from this project are the following:

- Benchmarks for Water Conservation / Water Demand Management in the Mining Sector: Key Indicators and Commodity-based Water Use Benchmarks (hereinafter referred to as the Benchmarks report);
- Guideline for the development and implementation of water conservation / water demand management plans for the mining sector (April 2015, this document);
- Standardised Water Accounting Framework– this report is to support the establishment of an on-line WC/WDM reporting system that would be integrated with an Electronic Water Use Licence Application and Authorisation System (EWULAAS) developed by DWS;
- Updated Best Practice Guideline G2: Water and Salt Balances to include a chapter to assist mines in summarising their operational water balances into a format that can be reported into an on-line SWAF system; and
- Draft regulations requiring the implementation of WC/WDM within the mining sector. These WC/WDM regulations will be incorporated into the GN704 regulation which is currently undergoing the process of revision.

Investigations that were undertaken to support the above project deliverables include the following:

1. Literature review to evaluate different approaches and methodologies followed internationally in setting water use targets and developing and implementing WC/WDM plans.
2. Development of a variables matrix that identifies characteristics of a generic mine water system that could have a major impact on the achievement of WC/WDM targets.
3. Undertaking of an extensive survey of representative South African mining operations to collect detailed data on current water management activities on mines and to obtain current water balance data in order that current water use efficiency (WUE) indicators could be determined and current WC/WDM measures being implemented could be evaluated.

These three key tasks were intended to provide the information that could be used by the project team in setting water use (WU) targets for the different commodity groups within the mining sector with the intention that such targets could provide clear guidance on the ultimate water use efficiency that each mine could and should aim for. The inherent assumption at the time of preparing the project terms of reference and proposal was that the outcome of these tasks would provide the information required to support the development of WUE targets as was described in Phase 1 project reports. The outcome of the work that was undertaken in fulfilment of the abovementioned three tasks can be summarised as follows:

1. The literature review clearly showed that no country in the world had set definitive and enforceable WUE targets for the mining sector. The reported literature and case studies indicated that substantial work had been done in developing methodologies for setting realistic and defensible WUE targets for a specific mining operation. The primary conclusion drawn from the literature review was that there were too many site and mining specific water variables that needed to be taken account of, which rendered the setting of national WUE targets impractical and unproven. It was also recognised that the level of accuracy, reliability and detail of water balances at mines were so varied that this problem would first need to be rectified before accurate baseline conditions could be developed to use as the basis for WUE target setting. This prompted Australia, the country most advanced with WC/WDM in the mining sector, to develop the Water Accounting Framework (WAF) as a standardised water balance information reporting system for mines that would serve as a precursor to the development of national or sector based WUE targets. This WAF was developed and is being implemented by participating mines to the Australian Minerals Council.

2. The development of the variables matrix for the South African mining industry, as part of this project,

also confirmed that there are many climatic, surface and groundwater, mining methods and operational variables that could influence WC/WDM opportunities on a mine. Furthermore, it was found that each of these variables could have a different effect on different mines, and that it was therefore not possible to identify or develop a generic mine water system with associated WC/WDM features or measures, that would in any way be scientifically or legally defensible, to consider the effects of all variables on WC/WDM status for such a generic mine. This conclusion supported the international consensus on this topic as found in the literature review.

3. The mine survey undertaken at 39 South African mines confirmed that a primary problem was the widespread lack of accurate and credible water balances that could be used as a baseline for the development of WUE targets. When undertaking an objective audit to identify those water balances that did not meet minimum requirements for a credible water balance for calculation of water use indicators, 23% of the mine water balances had to be rejected. Only 29% of the water balances were aligned with the minimum requirements as set out in the DWS Best Practice Guideline G2: Water and Salt Balances (BPG G2), while 48% of mines were found to have balances with significant deficiencies, but still broadly suitable for use in the project. The survey also found that on those few mines that had started addressing WC/WDM within their operations, current efforts were largely focused on replacement of imported water sources with alternative on-site water sources. It was also generally found that no significant effort had been made on improving water use efficiency through the development and application of a holistic WC/WDM plan, aimed at identifying water use efficiency measures that would ultimately lead to water use reductions or savings throughout the mine's operations.

   While reasonable representative data was obtained for the coal, gold and platinum commodity sectors, a further complication in target setting is that the data density for all the other mining commodities was insufficient and necessitated the aggregation of all these other commodities into a group called "other" sectors.

Based on the above findings from the first phase of the project it was concluded that it would not be scientifically or legally defensible to attempt to set national WUE targets that would be applied to all mines within the different commodity groups. Any targets that would be set, given the findings listed above, could have been challenged with little scientific basis for defending such targets.

The alternative process that was developed in order to initiate WC/WDM within the mining sector consisted of the following six components:

1. Definition of appropriate WUE indicators for the mining sector.
2. Calculation of the WUE indicators for the different commodity groups (coal, gold, platinum and other), based on the data collected during the site visits.
3. Determination of national WUE benchmarks (not targets as originally intended) 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).
4. Development of 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 status in the shortest possible time. These WC/WDM plans should be integrated into the mine's Integrated Water and Waste Management Plan (IWWMP).
5. Provision for a mine to report on its performance against its WC/WDM plan in a standardised on-line format that will be designed to integrate with the mine's water use licensing reporting requirements. This Standardised Water Accounting Framework (SWAF) will not replace the mine's detailed water and salt balance but will simply be a standardised format in which all mines are required to report on their achievement towards their WUE targets. This project will provide DWS with a detailed technical specification on the features and content of the SWAF and DWS will take responsibility to integrate this into the on-line Electronic Water Use License Application and Authorisation System (EWULAAS). A guideline document to assist mines to complete the SWAF will be developed and incorporated into an updated BPG G2.
6. Development of regulatory procedures that recognise progress with the development and rapid

implementation of mine's WC/WDM plans towards an improved WUE status.

The outcome of the first three steps is contained in a separate report entitled: **"Benchmarks for Water Conservation and Water Demand Management in the Mining Sector"**. The outcome of the fourth step is described in this report.

The outcome of the fifth step comes in two parts:

a) Firstly, a Standardised Water Accounting Framework (SWAF) to enable mines to report on the implementation of their WC/WDM plans into an on-line reporting system, and

b) Secondly, an update of the existing DWS Best Practice Guideline series that can be used by the mining industry and other users as a guide for the use of the on-line SWAF system.

Step six will be implemented through the current water use authorisation and regulatory processes where a mine's WUE status and/or rate of implementing WC/WDM measures will be considered in the allocation or authorisation of water use or the restriction of water use during drought conditions. Furthermore, regulations applicable to the mining sector are in the process of being revised and would include regulations that address WC/WDM within the mining sector.

The relationship between the abovementioned six steps is shown in Figure 1 below.

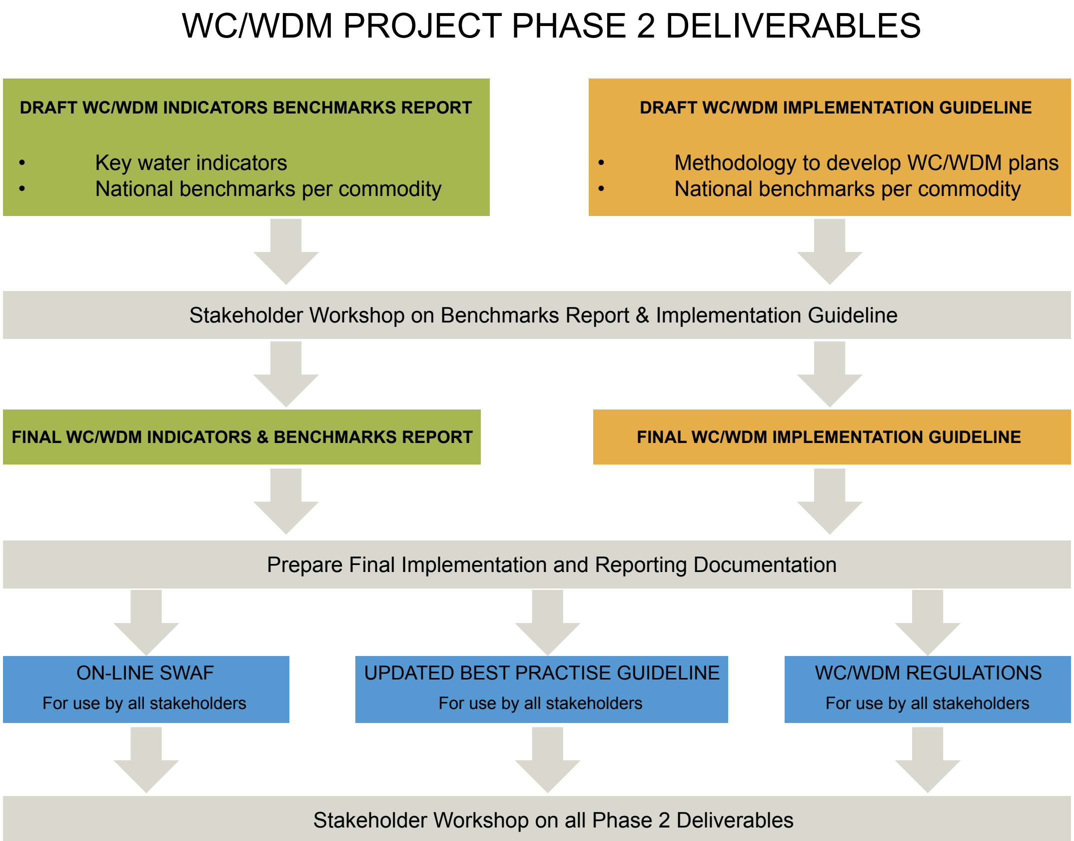

Figure 1: WC/WDM project phase 2 deliverables

Two significant previous reports have been published by the DWS that address WC/WDM planning in the mining industry:

- Best Practice Guideline H3: Water Reuse and Reclamation, 2006; and
- Water Conservation and Water Demand Management Guideline for the Mining Sector in South Africa, 2011.

Whereas both these earlier documents remain directly relevant for WC/WDM planning in the mining sector, this Implementation Guideline further supports and enhances WCWDM planning and implementation within the mining sector and it references the two abovementioned documents as and when required.

This report is referred to as the “WC/WDM Implementation Guideline” and has been prepared in a format that distinguishes between the responsibilities of the regulator (DWS and other Institutions) and the mining industry. A separate section has also been prepared that deals with the information compilation and reporting requirements. Each of the sections to be dealt with is captured and discussed in separate chapters:

Chapter 2: General Overview of Implementation Framework;

Chapter 3: Implementation Responsibilities of the Mining Industry;

Chapter 4: Actions that DWS would undertake;

Chapter 5: Specification of generic WC/WDM measures;

Chapter 6: Case Study: A practical guide for compilation and development of a comprehensive WC/WDM plan; and

Chapter 7: Conclusion.

2. GENERAL OVERVIEW OF IMPLEMENTATION FRAMEWORK

The methodology that has been developed to allow for the implementation of WC/WDM within the mining sector is shown in Figure 2 below, based on the generic implementation methodology as developed in the Phase 1 report (see Appendix A).

Key features of the proposed methodology are the following:

- There are clearly defined separate responsibilities and roles for the mining industry and for the regulator (DWS and/or other Institutions);
- The process incorporates the revision of Regulations GN704 in terms of the National Water Act, 1989 which include regulations relating to WC/WDM;
- The interactions between the mining industry and DWS are clearly defined;
- The methodology is broadly based on the generic implementation approach as reported in the Phase 1 report;
- The process allows for continuous improvement in WC/WDM;
- The process provides an incentive for mines to optimise their WC/WDM plans and to drastically improve their water use efficiency as quickly as possible;
- The process incorporates the principle of plan, act/implement, audit and modify (Plan, Do, Check, Act), to ensure that adherence with plans is tracked and monitored and that corrective actions are taken as and when necessary. Additionally WC/WDM plans will need to be formally updated every 5 years; and
- The methodology is integrated with the existing water licensing process and utilises the IWWMP as the vehicle for submission of the WC/WDM plan.

2.1. Mining Sector Responsibility

The responsibility of the mining sector is to compile accurate and computerised water balances in accordance with BPG G2 and revised regulations and to use these balances to develop a WC/WDM plan using the procedures set out in this WC/WDM Implementation Guideline and the BPG H3 (amongst others). In order for water balances to meet this requirement, they need to be capable of being used as reliable simulation tools to simulate the effects of identified WC/WDM management options on the WUE indicators (other than for the most basic of water balances, this would generally exclude spreadsheet-based water balances). The balances also need to be dynamic, must consider seasonal effects, must be regularly updated with new data and must be used by mine personnel responsible for day-to-day management of the mine water systems.

The mine will endeavour to develop a WC/WDM plan that enables it to set and achieve WUE targets that are well below the mine's current WC/WDM situation or WUE benchmarks within a defined timeframe. For existing mines, the WC/WDM plan will initially be submitted as an addendum to an existing IWWMP and will be integrated into and incorporated into the mine's IWWMP when the IWWMP is updated. New mines will submit their first WC/WDM plan as part of their first IWWMP. The mine will then implement its WC/WDM plan and complete an initial submission of its WC/WDM plan into an on-line Standardised Water Accounting Framework (SWAF) and will then also submit an annual SWAF update in order to monitor performance against and to report its adherence with its WC/WDM plan. It is also envisaged that the WC/WDM plan will be substantially reviewed and updated by the mine every 5 years.

Where mine are unable to develop a WC/WDM plan that brings their WUE status to a level below the national benchmarks, the mine will need to meet with DWS to consult and reach agreement on the reasons for this inability. Such reasons should primarily be linked to factors included in and discussed in the Variables Matrix (**see Appendix B**). This process is summarised in Figure 2 below. In future, DWS will give consideration to those mines that have progressed rapidly with the development and implementation of WC/WDM plans when water use licences need to be reviewed, when allocating water to new applicants or when water restrictions need to be implemented (**see Section 4 of this document**).

2.2. DWS Responsibility

The responsibility of the DWS is firstly to develop a standardised water accounting framework and computerised on-line reporting system (SWAF) that will ensure that all mines submit their water balance data in a standardised format to the DWS, allowing for on-line and standardised calculation and recording of the various WUE indicators and standardised ranking and assessment of a mine's WC/WDM plan and its compliance therewith. Additionally, the DWS is in the process of amending the current GN704 regulations. These new regulations, once published will also contain regulations on the development and nature of water balances and the need to develop WC/WDM plans by the mines and submit relevant performance data into the SWAF.

The DWS, in consultation with the mining sector will develop a standardised set of evaluation criterion to be used when reviewing WC/WDM plans. These criteria will be incorporated into the on-line SWAF in order to ensure that the rating and ranking of mines with respect to the adequacy of their WC/WDM plans and their WUE status will happen in a transparent and consistent manner. The results of the rating and ranking system will be used in a predetermined manner by DWS officials, in accordance with defined administrative procedures to facilitate decision making with regard to water use allocations and imposition of differentiated water restrictions. The DWS (or CMAs where these exist) will be able to access the SWAF rating and ranking results through pre-determined reporting outputs from the SWAF.

Where mines are unable to develop and implement a WC/WDM plan that brings their WUE indicators to below the national benchmarks, the DWS will consult with such mines to consider the motivations for such a sub-optimal WC/WDM plan and will then reach agreement with such mines on a case-by-case basis as to what would constitute an acceptable WC/WDM plan. In these consultations, primary consideration will be given to the factors described in the Variables Matrix (**see Appendix B**).

The DWS will also review the annual SWAF updates from the mines to determine that mines are on track with regard to their stated WUE targets that were included in the WC/WDM plan and to follow up with the mine when targets are not met. The DWS will also follow up with mines that do not submit WC/WDM plans or that do not submit annual SWAF updates to establish reasons therefore and to agree on appropriate corrective actions.

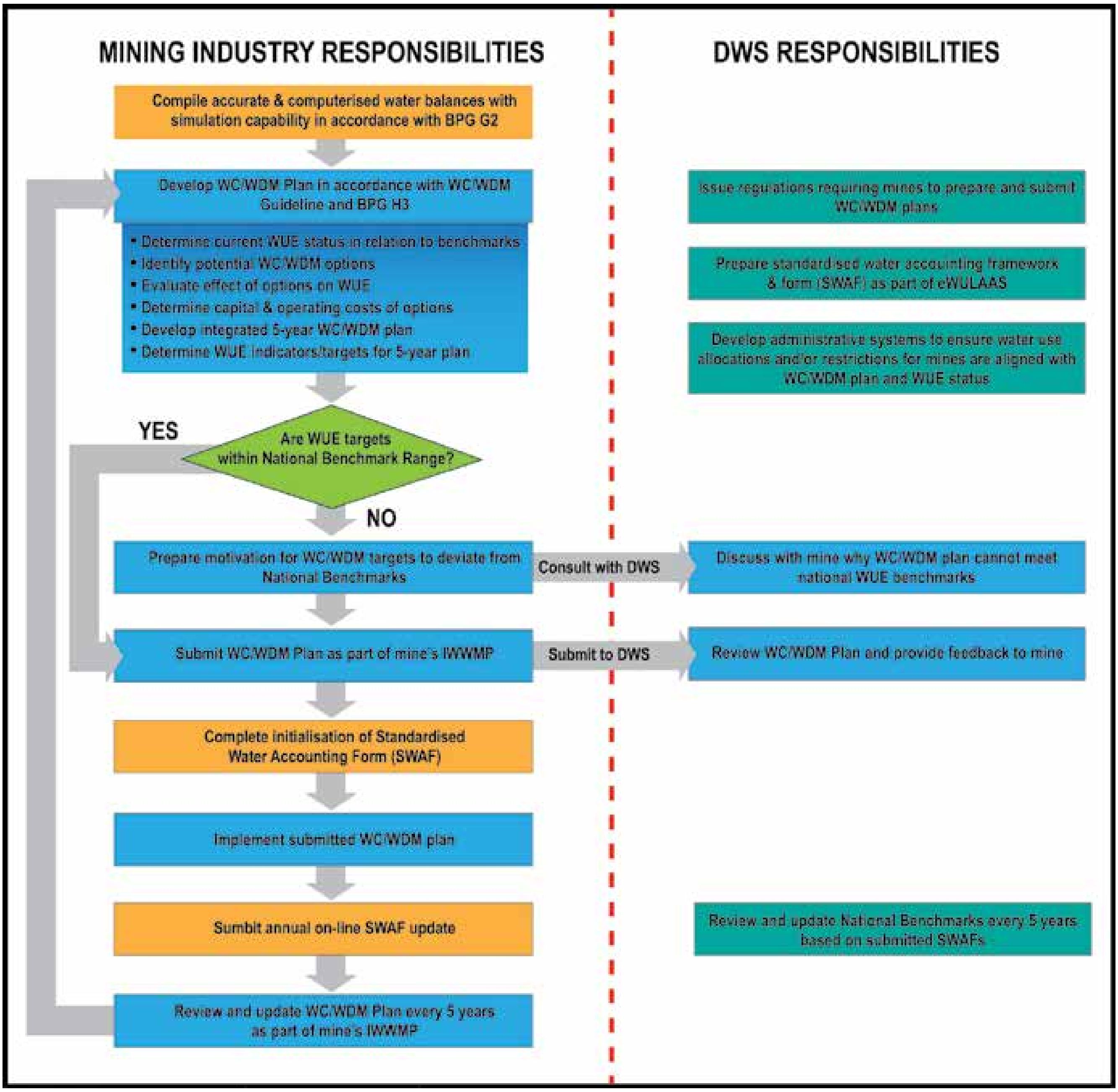

Figure 2: Implementation methodology for WC/WDM in the mining sector

In future it is envisaged that the DWS will utilise the SWAF rating and ranking results whenever the following decisions are made:

- Applications for water use licences, reviews or amendments;
- Applications for additional water use: water use licence applications;
- Water restrictions in times of drought; and
- Water reallocations to cater for demand changes in catchment: compulsory water use licensing processes.

The intention is for mines that:

a) have progressed the furthest with regard to developing and implementing a comprehensive WC/WDM plan;

b) that are clearly adhering to their water use efficiency targets; and

c) who are performing well below the national WUE benchmarks, to receive recognition, in accordance with transparent decision-making criteria compared to mines that are less water use efficient or performing poorly with regard to the above criteria. Such progressive mines will be seen by the DWS as effectively managing their water security and reducing their risk during times of high water stress.

A description of the responsibilities of the mining industry and the DWS with regard to applying the methodology set out in Figure 2 is provided in the next two chapters.

3. IMPLEMENTATION RESPONSIBILITIES OF THE MINING INDUSTRY

3.1. Compile Accurate and Computerised Water Balances

All mines are required to develop accurate and computerised water balances by utilising procedures as set out in BPG G2 and/or as per the water use licence conditions (where this is specified). The level of detail in the balances must, as a minimum, support the information requirements of the Standardised Water Accounting Framework (SWAF) – (**see Sections 3.4 and 4.2 of this report**). The BPG G2 provides the necessary information to enable mines to compile accurate and detailed water balances. Mines are required to pay particular attention to Appendix B of BPG G2 that specifies the minimum level of detail required for an acceptable water balance for each unit process that could be incorporated into a mine water balance. It is also important that the balance be dynamic insofar as ensuring that it can consider seasonal effects where relevant (e.g. unit processes affected by rainfall and/or evaporation) and that it will be capable of accommodating changes to water storage levels (e.g. pollution control dams, storm water dams, tailings disposal facilities, etc.).

In order for a water balance to be suitable for the development of a WC/WDM plan, it is critical that the computerised water balance is capable of being run in a simulation or predictive mode, where alternative WC/WDM measures and environmental conditions (rainfall/drought) can be simulated in terms of their expected effect or impact on the mine's water use efficiency indicators. This will be important to understand the effectiveness, preferred measures and sensitivity of the performance to environmental conditions.

The draft new regulations relating to water balances are as follows (note that these are draft regulations that still need to undergo review and consultation before being finalised and that the final regulations could differ):

Regulation 6: Water balances

(1) A person who submits an environmental management programme in terms of section 39(1) of the MPRDA shall compile a dynamic water balance for the activity based upon climatic variations and which includes all inflows and outflows from the activity and which reflects all surface and ground water interconnections with the water resource.

(2) A person referenced in regulation 6(1) or a holder of a mining right or production right shall ensure that the water balance -

- *(a) incorporates accurate values based upon measured volumes for the water abstracted, discharged, beneficiation process water intake, outflow to and return water from waste management facilities and water abstracted from mine workings;*
- *(b) incorporates accurate values determined from suitable measurement or modelling of rainfall, runoff, seepage and evaporation;*
- *(c) is kept current by ensuring that it:*
  - (i) *reflects all measured and modelled data and physical changes to any water system;*
  - (ii) *is available in electronic format which is capable of calculating a water balance; and*
  - (iii) *is updated with a frequency of not lower than on a monthly basis;*
- *(d) is submitted to the Department as part of the IWWMP, together with the monitoring data, unless stipulated otherwise in a water use licence;*

(3) All measuring devices used to develop the water balance shall be easily accessible, properly maintained, calibrated and in good working condition.

The methodology for developing a water balance is shown in Figures 3, 4 and 5 below as taken from BPG G2. BPG G2 also contains a worked example of how the methodology set out in these Figures should be practically applied.

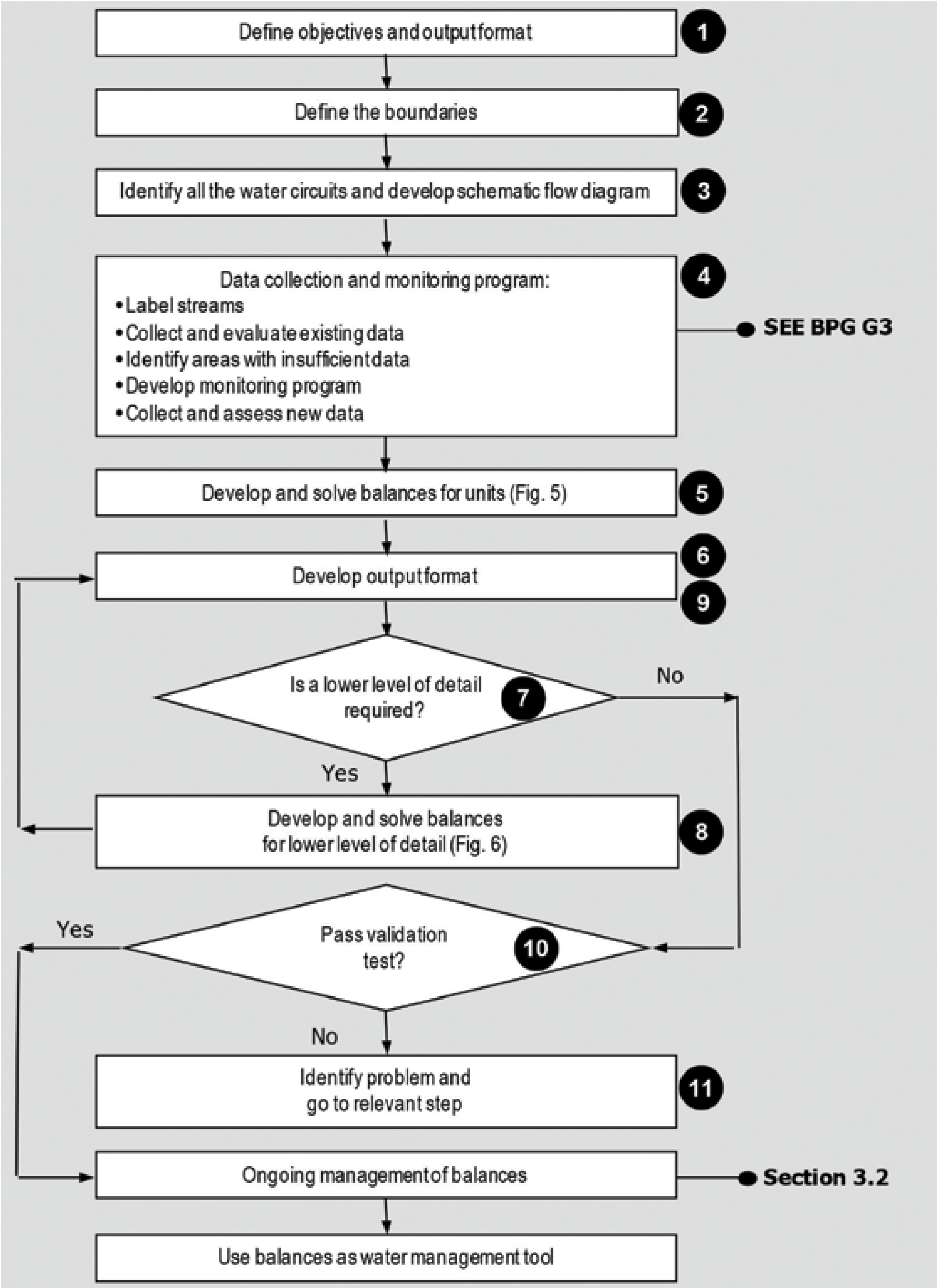

Figure 3: Methodology for development of a water balance (source BPG G2)

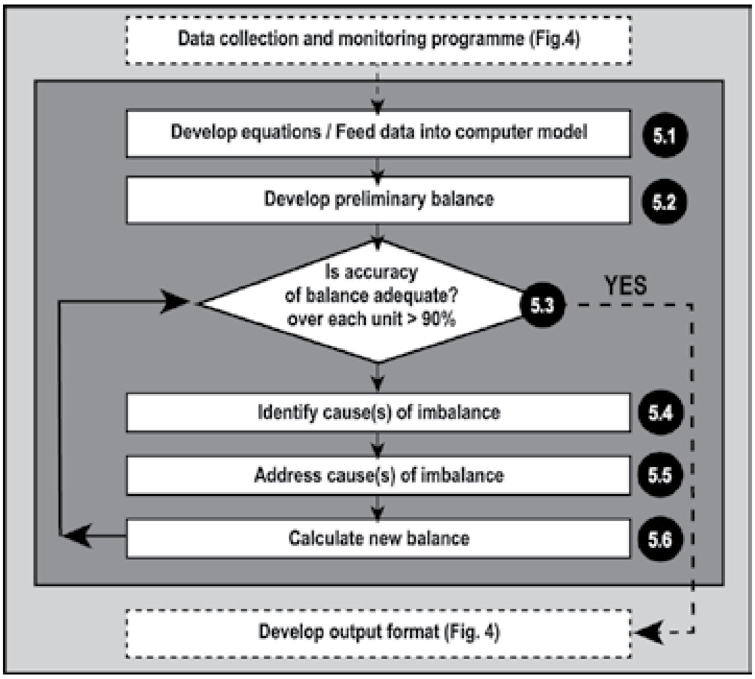

Figure 4: Flow diagram of process for step 5 (source BPG G2)

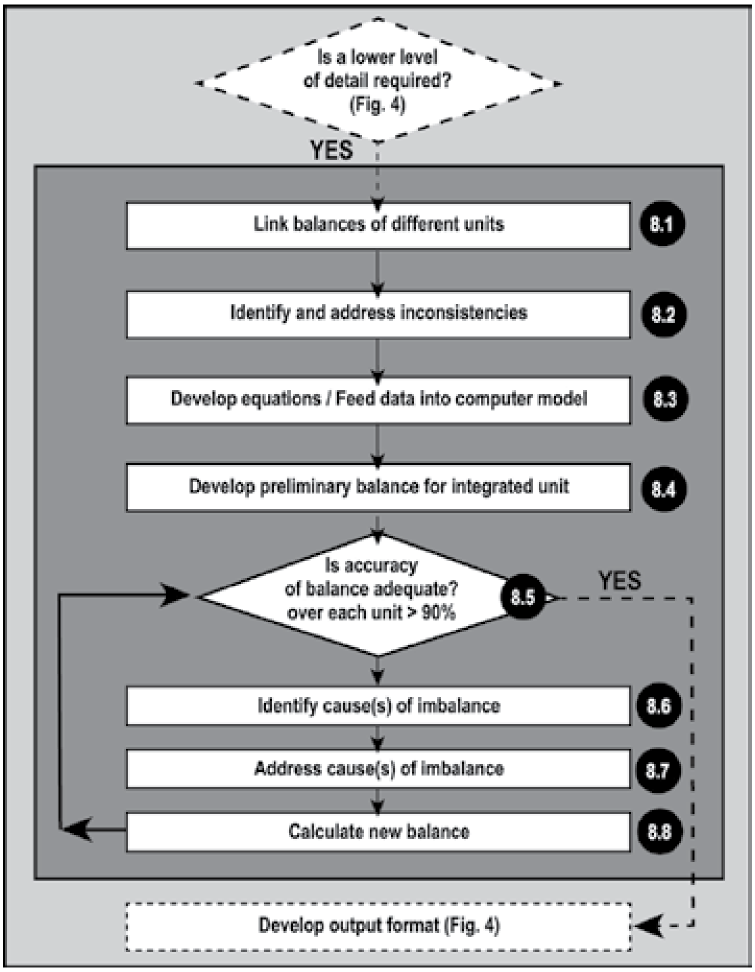

Figure 5: Flow diagram of process for step 8 (Source BPG G2)

The primary reasons for specifying that the water balance should be computerised are twofold:

- Firstly, to ensure that it is structured as a management tool that is capable of accepting new data inputs on a regular basis from the mine's monitoring programme (i.e. meets the "dynamic" criterion that would be specified in the regulations); and

- Secondly, to ensure that it is structured in a manner that allows it to be used as a simulation tool to evaluate the effects of various management options/measures on the water balance and therefore on the mine's water use efficiency indicators (**see Section 3.2 below**).

There are various computer programs/software available that could be used to construct the computerised water balance and BPG G2 is not prescriptive about which should be used. The water balance that is developed should however, be properly calibrated to ensure that calculated and modelled values correspond with actual flows measured within the reticulation system. The role of the water balance in the process of developing a WC/WDM plan is shown in Figure 6 below.

3.2. Develop the WC/WDM Plan

The procedure to be followed when mines develop water use efficiency targets is fully described in the DWS *Water Conservation and Water Demand Management Guidelines for the Mining Sector in South Africa.* This WC/WDM Guideline describes a methodology that mines should follow to set targets and as such also extensively draws on the relevant DWS Best Practice Guidelines. The broad steps set out in the WC/WDM guideline are based on three-phases:

- Assessment of current WC/WDM status;
- Planning for WC/WDM measures and opportunities; and
- Implement and manage WC/WDM measures and mine water system (**see Section 3.3** below).
- These steps are further expanded on in the WC/WDM Guideline. However, a more detailed methodology and flowchart is presented in Figure 6 below for the Assessment and Planning Phases. **Section 4.1** of this document also indicates the draft regulations mandating WC/WDM that are currently under consideration.

3.2.1. Determine current WUE indicators for the mine

The activities described in the first two steps are largely covered in **Section 3.1** above as they relate to the development of a detailed water balance. Once the detailed water balance has been completed, the current WC/WDM status of the mine can be determined with respect to the following WUE indicators, with these indicators being calculated as described in the Benchmarks for Water Conservation/Water Demand Management in the Mining Sector report:

- Total water use (volume – m^3/day or kl/day);
- Consumptive water use (volume – m^3/day or kl/day);
- Volumes of wastewater lost through e.g. discharges, seepage and evaporation (volume – m3/day or kl/day);
- Total specific water use – total water use per production measure (m^3 per ton of ROM ore);
- Consumptive specific water use - consumptive water use per production measure (m^3 per ton of ROM ore);
- Percentage of the total volume of wastewater generated (discharges, seepage, evaporation, unspecified sinks) that is not reused (reported as a percentage of consumptive water use) (%); and
- Water recycling ratio (all recycle streams added together and reported as a percentage of total water use) (%).

Once the mine has measured its performance with respect to the abovementioned indicators, it could be compared against the national benchmark values for the relevant commodity (as reported in the Benchmarks report) in order to determine how the mine currently performs in comparison to the benchmarks. This constitutes an internal benchmarking process and a performance that is better than the national benchmarks does not motivate for reduced effort in the mine's own WC/WDM plan. It must again be emphasized that the benchmark values do not represent aspirational WUE values as none of the mines included in the survey that led to the development of benchmarks can be viewed as having optimised WC/WDM or optimised WUE indicators. Each mine must still develop its own optimal WC/WDM plan with the most ambitious WUE targets that it can practically meet in order to obtain the best possible rating and ranking within the previously mentioned on-line SWAF system. The benchmarks are more relevant for situations where mines cannot develop a WC/WDM plan that brings their WUE targets below the benchmarks, necessitating a consultation with DWS as shown in Figure 6 below.

The best manner for a mine to manage its water security risk (regardless of regulation) is to advance as rapidly and effectively as possible in implementing the most progressive WC/WDM plan that addresses its water resource constraints. As such, the assessment of current WUE status against national benchmarks should be seen as the minimum performance and not the primary driver in defining the importance of the WC/WDM plan.

3.2.2. Identify a range of potential WC/WDM measures/options

There will be many different potential management measures/options that can be identified for a mine that could have a positive impact on its WUE indicators. The range of potential options implemented however, will differ from mine to mine, although there will be certain options that will be common to most mines. **Chapter 5** of this report lists a range of generic management measures that could be considered by a mine, although these options are not exhaustive and additional site specific measures should also be identified. Conversely, these options will not always be applicable to every mine.

The objective of this step though, is to engage in a "brain storming" exercise with specialists who understand the nature of the mining, beneficiation and residue disposal operations at that mine. For ease of assessment, it is recommended that the identified options be divided into three broad groups as follows:

1. Options to reduce consumptive water use;
2. Options to reuse / reclaim water; and
3. Options to use alternative operational technologies that use less water, e.g. "clean technology".

One of the reasons for classifying the identified options into the above three groups is that they, broadly speaking, represent a natural order of priority in terms of ease and probable cost of application. It can therefore generally be expected that costs and timeframes of implementation will increase as the mine moves from the first category of options to the third category. Either during the "brain storming" session, or thereafter, it will be necessary to describe and document each identified option in terms of the potential impact that it would have on water use at the immediate point of application, in a manner that can be inputted into the water balance model for simulation purposes.

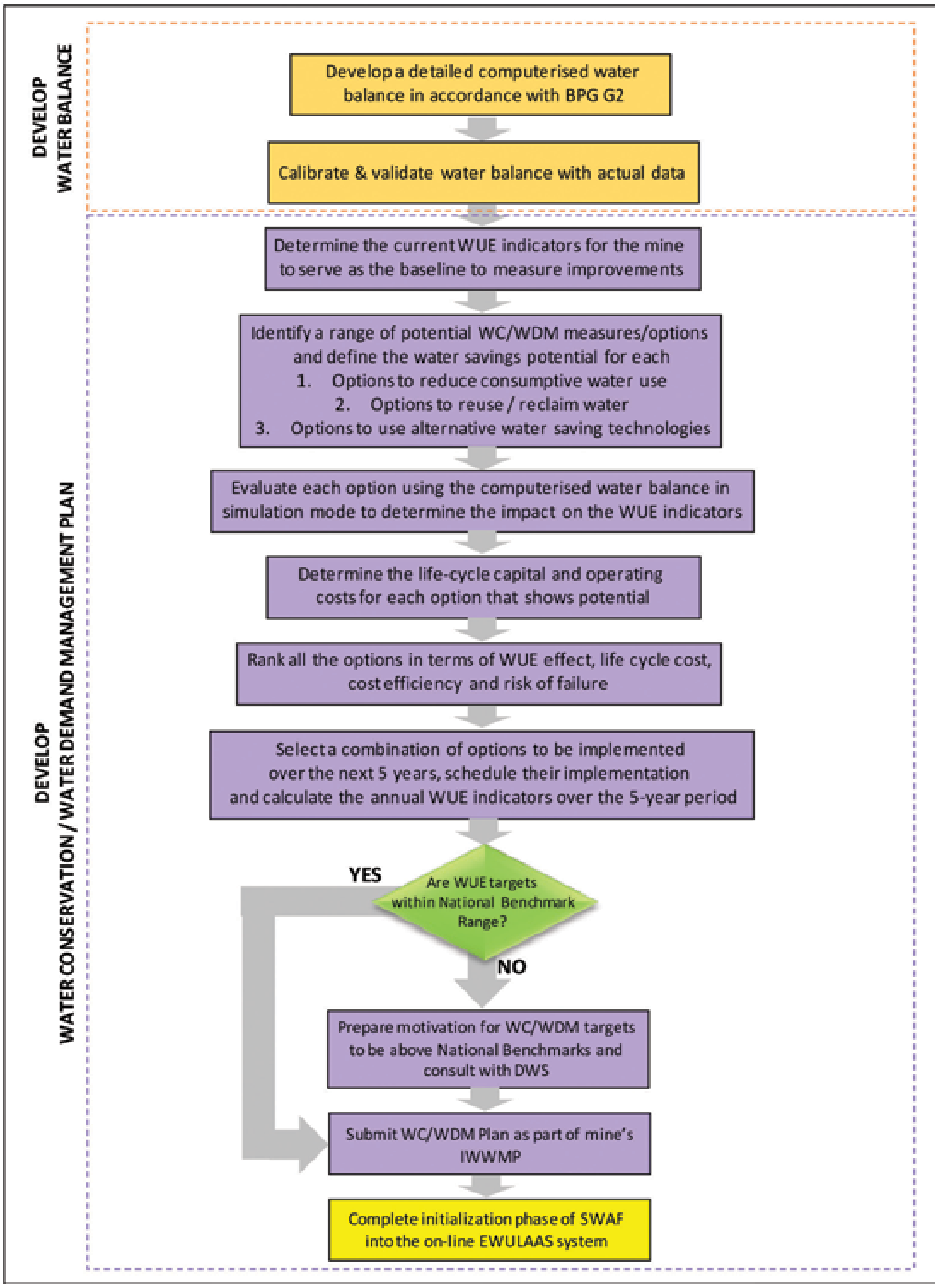

Figure 6: Methodology for the development of a WC/WDM plan

3.2.3. Evaluate each option using the simulation water balance model

As discussed previously, it is important that the water balance model that has been developed by the mine in **Section 3.1** above, is able to operate in a simulation mode, meaning that the model must be able to consider changes to any one or more of the unit processes included in the water balance network and be able to predict the effect of this change on the overall water balance. More specifically, the model must be able to simulate the effect that each of the options identified would have on water inputs and water outputs in order that changes to the WUE indicators can be calculated and hence the best options can be selected for implementation.

In this step, each potential option would be simulated on its own and the calculated change in each of the WUE indicators must be determined and recorded (cumulative effects of a combination of options are considered later as discussed in **Section 3.2.6** below). In undertaking this exercise it is considered critically important to carefully check the calculations to ensure that the proposed options have been accurately simulated. Before comparing the results of simulations for similar options between different mines or to literature values, care must be taken to consider the effect of the different variables as described in the variables matrix (**see Appendix B**), on the simulation. This implies that an option which is assessed to have a major beneficial impact on one mine may not have a similar beneficial impact on another and different mine.

It is recommended that the outputs of the simulations be entered into a tabular format where they can then easily be ranked in terms of effect (cost / improvement in WUE, risk of failure, etc.).

3.2.4. Determine the life-cycle capital and operating costs for each option

Some options will be simple and inexpensive to implement while others could be complex, costly and could require significant process and infrastructure changes. The different options that are evaluated could be considered and ranked not only in terms of beneficial impact on the mine's WUE indicators but also on the cost, risk and operational implications of each option. It is proposed that the capital and operating costs of each option be considered over the remaining life of the mine and that they be added and reported in the form of Net Present Value (NPV) using the rate of return relevant for that mine. The more accurate the cost estimates can be, the better and more reliable will be the decisions that follow in constructing an integrated 5-year WC/WDM plan.

In many cases it may be desirable to undertake a first assessment of WC/WDM management options based on rough first-order cost estimates. However, before a final WC/WDM plan is submitted with a commitment to an implementation schedule, a reasonably confident assessment of costs will be required. The annual performance reporting into the on-line SWAF will assess the mine's compliance with its commitments made in the WC/WDM plan and it is therefore critical that mine's ensure that the plan they submit is adequately resourced as non-compliance will affect the mine's rating and ranking negatively.

3.2.5. Rank all options

All options that have been simulated and for which life cycle cost estimates have been determined should be entered into a tabular format where, it is recommended that the following information could be reported:

- Baseline WUE indicators representing the current mine situation;
- Name of option;
- Total change in each of the WUE indicators as determined by way of water balance simulation;
- NPV for the option (over life of mine);
- Cost effectiveness reported as R/m3/annum of total input water saved;
- Confidence (high, medium or low) in result of simulation;
- Confidence (high, medium or low) in cost estimate;
- Confidence (high, medium or low) in success of option (inverse to risk of failure); and
- Time required to implement the option.

Additional information that the mine may wish to add is: change in each of the WUE indicators for each of the next 5 years or longer (where the effects are different from year to year; capital and operating costs for each year that the option will be in force; etc.).

Based on the above information, the different options should be ranked. It is not desirable to be prescriptive as to which factors should hold the greatest weight when undertaking the ranking, as this may vary from mine to mine depending on various circumstances such as remaining life of mine, regional water security, corporate policies etc. However, at the end of the day, the selected options taken forward into the 5-year WC/WDM plan should reflect the mine's optimum WC/WDM plan for that period. This is particularly important given the rising scarcity of water supplies in South Africa and the very clear linkage between a mine's WC/WDM and WUE indicator status and its surety of water supply. One of the primary tools that a mine has to manage and mitigate its water security risk, is to have the best and most advanced WC/WDM plan (in terms of content, WUE indicator targets and actual implementation of the plan) in comparison with other water users within its catchment.

3.2.6. Select combination of options for integrated 5-year WC/WDM plan

The evaluated and ranked options should finally be considered and a range of options should be selected and documented that cumulatively should enable the mine to move from its current status in terms of WUE indicators to well below the national benchmark values within the 5-year timeframe of the plan. The water balance model should then be used to simulate the integrated cumulative plan in order to determine the WUE targets that can be achieved when the integrated cumulative plan is implemented over at least the next 5 years. WUE targets should then be set for each of the 5 years as these will be entered into the SWAF during the initialization phase and the mine's performance in achieving these WUE targets will be evaluated, rated and ranked during the annual performance reporting. A schedule of implementation for the different management options must be included in the integrated WC/WDM plan (where implementation of an option extends over more than one year, the percentage completion in each year must be included in the schedule. This is required in order to assess compliance with the WC/WDM plan during the annual SWAF reporting.

The mine should also bear in mind that its performance in terms of WC/WDM is the primary water security driver for its operations. Additionally, as the mining industry as a whole progresses with the development and implementation of WC/WDM plans, it is logical that national WUE benchmarks will improve over time. The requirement for mines to report their annual performance into the on-line SWAF system will also make it easy for the DWS to access this data and to publish new national WUE indicators from time to time. All these above factors imply that mines should not be aiming to just comply with current benchmarks, but should be aiming to improve their WUE indicators to the maximum extent possible.

The integrated 5-year WC/WDM plan should then result in a set of annual targets for each of the WUE indicators, indicating clear and considerable improvement in the mines water use efficiency, coupled with annual costs associated with the plan for the mine.

3.2.7. Evaluate adequacy of proposed 5-year WC/WDM plan

The annual targets for each of the WUE indicators could be compared to the national benchmark values that apply at the time when the plan is being developed. Currently, the benchmark values are reported for each of the major commodity groups – gold, coal, platinum and other – in the Benchmarks report. It is important to demonstrate that the integrated 5-year WC/WDM plan will ensure that the mine moves significantly below the current WUE benchmark values for that mine/commodity group within the 5-year term of the WC/WDM plan (or longer if adequately motivated and agreed with DWS) before the plan can be considered acceptable and ready for submission to DWS for review. If the integrated WC/WDM plan does not bring the mine into line with the WUE benchmark values, then the mine will need to consult with DWS to discuss the specific reasons for this deviation and to reach agreement that the proposed WC/WDM plan is acceptable.

However, as stated elsewhere in this report, compliance with the WUE benchmarks will not necessarily mean that the mine has a good WC/WDM plan (the mines on which the benchmarks are based do not necessarily exhibit optimised WUE status) and it is certainly no guarantee that the mine will receive the necessary credits to give itself a high surety of water supply. Each mine must prepare a WC/WDM plan that demonstrates that it has considered all the viable WC/WDM options and that it has developed a unique WC/WDM plan that optimises water use for its own unique operations. However, irrespective

of whether benchmarks are achieved, not achieved or exceeded, all mines need to prepare WC/WDM plans that can demonstrate that they have considered all the viable WC/WDM options and that their WUE targets are, in fact, optimal for their conditions.

3.2.8. Prepare motivation for deviation from the WUE benchmarks

In exceptional cases where the proposed integrated 5-year WC/WDM plan is predicted not to at least meet the WUE benchmarks then further investigations will be required. Where possible, the mine should then go back to Section 3.2.6 above and select additional or different options to be incorporated into the 5-year WC/WDM plan that are capable of meeting and preferably improving on the published benchmark values. If this is not successful, then it may be necessary to go all the way back to **Section 3.2.2** to identify additional options that can be simulated and costed with the intent of enabling the integrated 5-year plan to at least meet the national benchmark values.

It is expected that the large majority of mines would prepared WC/WDM plans that significantly improve on the WUE benchmarks in order to obtain a good rating and ranking within the SWAF system, thereby ensuring a high degree of water surety for their operations. However, it must be clearly stated that there will be a small amount of mines that will be able to provide a valid motivation as to why they cannot meet the national benchmark values for some or all of the WUE indicators. The reasons for this could vary, but could include factors such as a unique combination of variables (**as described in the variables matrix – see Appendix B**) that result in the mine being considered as a special case.

It is unlikely that a mine will be able to motivate to do nothing to improve its WUE performance, as there will generally be some measures that can be readily implemented at each and every mine. However, in any situation where the mine intends to submit a WC/WDM plan that does not bring it into line with national WUE benchmark values, such deviation will need to be supported by a very sound technical motivation that will be considered by the DWS in direct consultation between the mine and the DWS. It is envisaged that such a consultation should be documented by way of meeting minutes or a signed letter from DWS confirming the outcome of the meeting and that such documentation should then be included as an Appendix to the WC/WDM plan.

Those mines that do clearly incorporate all viable management options into their WC/WDM plan and succeed in setting WUE indicator targets that significantly improve on the published WUE benchmarks are those mines that will have the highest probability of succeeding in managing the risk associated with surety of water supply and surety of continued business operations. The rating and ranking system that will be incorporated into the on-line SWAF will objectively determine which mine's WC/WDM plans are the best.

3.2.9. Compile and submit a 5-year WC/WDM plan

Once the mine has moved through the activities described in Section 3.1 and Sections 3.2.1 to 3.2.8 above, the mine will need to prepare and submit a documented WC/WDM plan. The initial 5-year WC/WDM plan will be submitted by the mine as an addendum to its existing IWWMP (for those mines that have already compiled and submitted an IWWMP to the DWS and where an update is only scheduled 2 or more years later). Mines that are scheduled to update their IWWMP within the next 2 years will submit their first WC/WDM plan together with their upcoming IWWMP revision. Future updates (every 5 years) of the WC/WDM plan will be incorporated into and synchronised with updates to the mine's IWWMP. New mines will submit their WC/WDM plan together with their initial IWWMP and/or water use license application.

While mines should submit a WC/WDM plan that has a minimum of a 5-year plan and schedule, mines are encouraged to submit plans with a longer schedule showing their longer term intentions to optimise their WUE targets. In such situations, it is accepted that the portion of the plan beyond 5 years will be reviewed and updated when the mine submits its next formal updated WC/WDM plan.

3.2.10. Complete initialisation phase of SWAF

The on-line SWAF system that is being developed will have 2 major components, namely an initialisation phase and a performance / updating phase. The initialisation phase will need to be completed as soon as the mine has completed and submitted its WC/WDM plan. The precise format of the SWAF is still under development but the initialisation phase will require mines to enter at least the following information into the on-line reporting system:

- Current water balance information in a standardised format;
- Current baseline WUE values for each of the WUE indicators;
- WUE targets for each of the subsequent 5 years for each of the WUE indicators; and
- Management options that are to be implemented in each of the subsequent 5 years.

The full detailed WC/WDM plan will also be uploaded as a PDF file, although the abovementioned data will be entered separately directly into the on-line system in order to allow the system to undertake the rating and ranking process. Annual updates will report on progress in implementing the management options and achievement of set WUE targets.

3.3. Implement the WC/WDM Plan

Once agreement on the submitted 5-year WC/WDM plan and its WUE targets have been reached with the DWS, the mine must ensure that it implements the submitted plan. In practice, mines should generally start implementing their WC/WDM plan as soon as they have completed it and submitted it to DWS, with the inherent flexibility to make changes, should significant changes be requested by DWS after the review period.

To ensure that implementation is successful, the 5-year plan should have clear management responsibilities, timeframes and allocated budgets for each of the options that are to be implemented.

Compliance with the mine's stated and agreed WUE targets will be measured and managed by way of the annual SWAF reporting system as described in **Section 3.4 below**.

3.4. Complete Standardised Water Accounting Framework

All mines that are required to have water use licenses will be required to complete an on-line Standardised Water Accounting Framework (SWAF) that will be developed by DWS (see Section 4.2). Additional information regarding the principles underpinning the SWAF is also provided in **Appendix A** to this report.

The purpose of requiring mines to complete an on-line SWAF is primarily for mines to monitor implementation and to report progress made with the implementation of their plan, report on their water use efficiency indicators to the DWS in a standardised and transparent format that enables the calculated water use efficiencies of all mines to be directly compared against each other. The SWAF information is also critical to enable the DWS to determine the success of WC/WDM implementation on individual mines and within regions and to obtain the information required to undertake the rating and ranking process required to enable mines to receive the credit due to excellent WC/WDM progress. The site engagement process included as part of this project clearly highlighted that the lack of uniformity in water balance information and reporting formats made it very difficult to determine the actual status of WC/WDM in the mining sector. The foundation of a rational and successful national WC/WDM strategy for the mining sector is clearly dependent on accurate water balances and standardised reporting formats.

As discussed in later sections of this report, the proposed SWAF will be largely based on the Water Accounting Framework developed by the Minerals Council of Australia and summarised in **Appendix A**.

The SWAF will be incorporated into the DWS' on-line water use licensing system (EWULAAS). A new Best Practice Guideline G6: Standardised Water Accounting Framework will be prepared to give mines clear guidance as to how they should extract information from their operational and more detailed water balances in order to provide data compatible with the SWAF reporting requirements.

3.5. Determine Water Use Efficiency Status

The on-line SWAF is intended to incorporate built-in equations that will calculate the mine's current water use efficiency (WUE) status with regard to each of the key indicators described above and in the Benchmarks report. This approach will ensure that there is a consistent and accurate determination of the mine's WUE indicators.

The on-line SWAF must be updated on an annual basis (starting within one year after the mine has commenced implementation of its approved WC/WDM plan) using the outputs from the computerised water balance that the mine has developed. The SWAF will automatically calculate the mine's revised WUE performance indicators and use this data to determine the rating and ranking of the mine compared to other relevant mines (e.g. in the same commodity group or in the same catchment). The SWAF will also allow for the uploading of an annual Water Conservation Plan as described in the 2011 DWS WC/WDM Guideline. **The key deviation from the DWS WC/WDM Guideline format for the annual Water Conservation Plan is that it must include reporting on all the key WUE indicators listed in the Benchmarks report and is therefore referred to as the WC/WDM Performance Report**. Additionally, the Water Conservation Plan must present a statement on whether the plan as it is being implemented is successfully meeting the internal WUE targets, or whether an update to the plan is required.

3.6. Update the WC/WDM Plan

The process described in Section 3.2 above should be repeated every 5 years in order to produce an updated 5-year WC/WDM plan. The need for regular 5-yearly updates is firstly linked to the fact that mining plans are regularly changed and there is a need to ensure that the WC/WDM plan remains relevant. Secondly, it is envisaged that the WUE benchmarks may be reviewed and updated using the data that will accumulate in the on-line SWAF database and that the mine's WC/WDM plans may need to be updated to ensure that it stays well ahead of the any updated benchmarks.

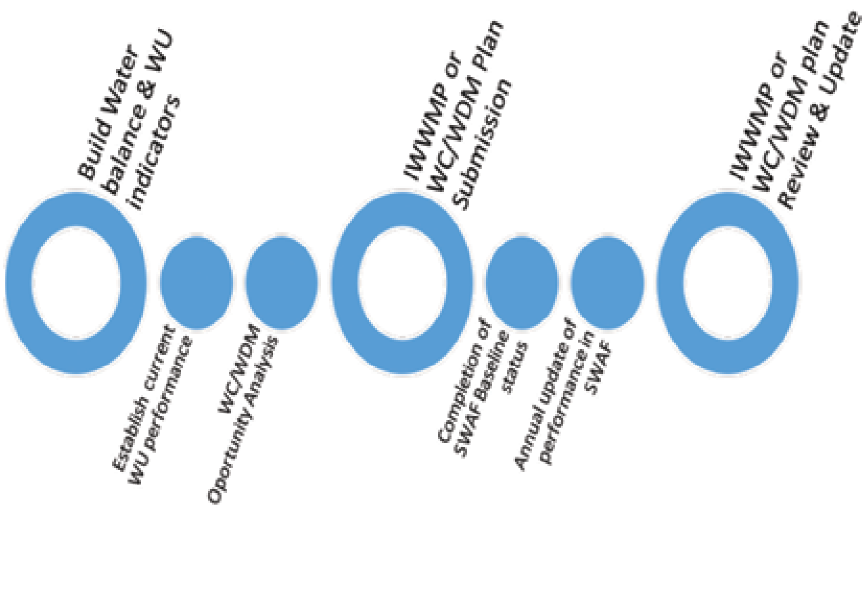

Figure 7: Overview of WC/WDM planning process

4. ACTIONS THAT DWS WILL TAKE

While the mines have a clear set of responsibilities and actions that they need to undertake in implementing WC/WDM within the sector, DWS and its institutions, e.g. CMAs that have been set up to act on behalf of the DWS, would also have a clear set of responsibilities and actions.

4.1. Issue Regulations Mandating WC/WDM

Although the NWA and the existing legislation and licensing process adequately incorporates WC/WDM considerations, DWS is currently engaged in a process of reviewing the existing GN704 regulations in order to present a set of regulations that is closely aligned to current best practice and the DWS Best Practice Guidelines in particular, in order to further strengthen or enhance the need for the sector to improve its WUE status. While the draft regulations still need to be promulgated, they

do include a section (section 7) that deals with WC/WDM as follows:

Regulation 7. Water conservation and water demand management

(1) A holder must use all water on the mine efficiently and shall:

- *(a) minimise the total water intake;*
- *(b) avoid the use of water where possible;*
- *(c) implement "good" housekeeping and operating practices; and*
- *(d) maximise the reuse of contaminated water.*

(2) A person who submits an environmental management programme in terms of section 39(1) of the MPRDA shall develop a water conservation and water demand management plan, which -

- *(a) quantifies the water use efficiency of the activity;*
- *(b) contains the mine water management and water loss strategies and programmes;*
- *(c) sets annual targets for improved water use efficiency for the mining activity, beneficiation and waste disposal practices and stipulates which measures will be implemented to achieve the targets on the mine;*
- *(d) reports on the implementation of more efficient processes, equipment designs, and other on-site measures to enable the mine to avoid and reduce water consumption; and*
- *(e) reports on the implementation and reduction of total water demand.*

(3) The holder of a mining right or production right shall -

- *(a) report on actual performance against the approved water conservation and water demand management plan annually;*
- *(b) update the water conservation and water demand management plan at a frequency of every five years or less;*
- *(c) execute the water conservation and water demand management plan; and*
- *(d) submit the water conservation and water demand management plan to the Department as part of the IWWMP, unless directed otherwise by the Department.*

The requirements for a WC/WDM plan are clearly set out in this Implementation Guideline and mines should start the WC/WDM planning process immediately and should not wait for the issuing of new regulations.

4.2. Standardised Water Accounting Framework

A critical issue in assessing and ensuring that WC/WDM measures are correctly implemented is to have confidence that the information reported by the mines is credible and that all mines report information in a uniform format. This challenge has been recognised elsewhere in the world and most particularly in Australia where the Minerals Council of Australia (MCA), which represents most of the Australian mining industry, developed a Water Accounting Framework (WAF) that all its members are actively encouraged to adopt and use in reporting their water information. The MCA also developed a computerised system (in Microsoft Excel format) that ensures that all mines that use the tool report their information in the recommended standardised format. A further discussion on the MCA WAF is presented in Appendix A to this report.

While a more detailed discussion is presented in Appendix A, it is believed that the approach adopted in the MCA WAF holds significant benefit for the South Africa mining sector and it is therefore being adopted, with the necessary modifications, to make it suitable for the implementation and management of WC/WDM in the South African mining sector.

By developing a SWAF that can be completed on-line via the internet (as part of the DWS EWULAAS), the assurance will be given that all mines that require a WUL, are capable of reporting their information in the same standardised format which, in turn, will allow the calculation of WUE indicators for all mines in a standardised and approved manner. The EWULAAS does incorporate the necessary security checks to ensure that only authorised persons can enter data on behalf of the mine. The on-line system will also ensure that this information is directly available to the relevant personnel at DWS and will enable the DWS to also keep track of whether or not mines are meeting the WUE targets set out in their WC/WDM plans and will also provide the data to allow for future updating of WUE benchmarks.

The SWAF system will incorporate an initialization phase and an annual performance update phase, both happening through an interactive on-line system. The initialization phase will be completed by the mine as soon as it has completed and submitted its WC/WDM plan, while the annual performance update will continue for the life of mine. The data entered into the SWAF will be utilised to automatically calculate a rating of the adequacy of the WDC/WDM plan and the mine's performance in meeting WC/WDM and WUE objectives. This rating system will be used to rank mines (within commodity groups or catchment management areas) based on agreed criteria. The manner in which rating and ranking is determined will be transparent to each individual mine.

4.3. Review WC/WDM Plans

Mines that have submitted a WC/WDM plan (either as an Addendum to their IWWMP for the first time, as an integral part of their IWWMP or as updated plans) are required to demonstrate that their plan will enable them to improve their WUE indicators to well beyond current WUE benchmarks within a 5-year period. The extent to which this has been achieved in the submitted WC/WDM plan would be reviewed and assessed. While the DWS will not formally approve the submitted WC/WDM plan, it will communicate with the mine to provide feedback on the submitted WC/WDM plan. The adequacy of the WC/WDM plan will be assessed automatically in the on-line SWAF system through a consistent rating and ranking process that will be well-documented and transparent.

If mines develop and submit a WC/WDM plan that includes WUE targets that are higher than the published benchmarks, then the mine will need to engage with the DWS to provide a detailed motivation as to why it cannot meet the WUE benchmarks. It is envisaged that such a motivation would draw on the issues raised and presented in the **Variables Matrix attached as Appendix B**.

Finally, the DWS must confirm that there are clear time frames, budgets and responsibilities for the implementation of the WC/WDM plan. Should the submitted WC/WDM plan meet the DWS requirements and there is confidence that the internal WUE targets are well below the current benchmarks and that budgets, timeframes and responsibilities have been incorporated, then the plan should be considered adequate and

DWS should communicate this formally to the mine. Alternatively, if the mine's submitted WC/WDM plan is not considered adequate or is found to exclude important information, then this will also be communicated to the mine. Additionally, mines that do not submit a WC/WDM plan timeously or in accordance with this guideline run the risk of contravening the proposed new regulations which will make WC/WDM plans mandatory.

The mines need to understand, however, that the primary consequences of an inadequate WC/WDM plan will reflect in a poor rating and ranking within the SWAF system which will have the effect of placing the mine's future security of water supply at risk.

4.4. Review and Update National WUE Benchmarks

The national WUE benchmarks that were developed as part of this project, using the process reported in the Benchmarks report, are based on data collected from 39 mines in 2013 and in an environment where many mines did not have reliable and accurate water balances or had not yet implemented any substantial WCWDM measures. In addition, there was no standardised format in use within the mining industry for reporting water use and discharges, making it difficult to develop national WUE benchmarks. The long-term strategy on WC/WDM is one of continuous improvement and it is therefore expected that the national WUE benchmarks will also be refined and updated in future and that they would generally be expected to become more stringent with time.

By adopting the SWAF approach to water information reporting, DWS will automatically, on an annual basis, obtain updated information from each mine on their actual WUE status. This information can be used to update the national WUE benchmarks in a manner that is schematically shown in the Figure below. It is expected that as WC/WDM strategies and plans are implemented within the mining sector and annual updated information is received via the SWAF, that the DWS would be able to use the submitted information to update the benchmarks. It is furthermore expected that the average benchmarks will become lower and that the range between minimum and maximum values will also reduce.

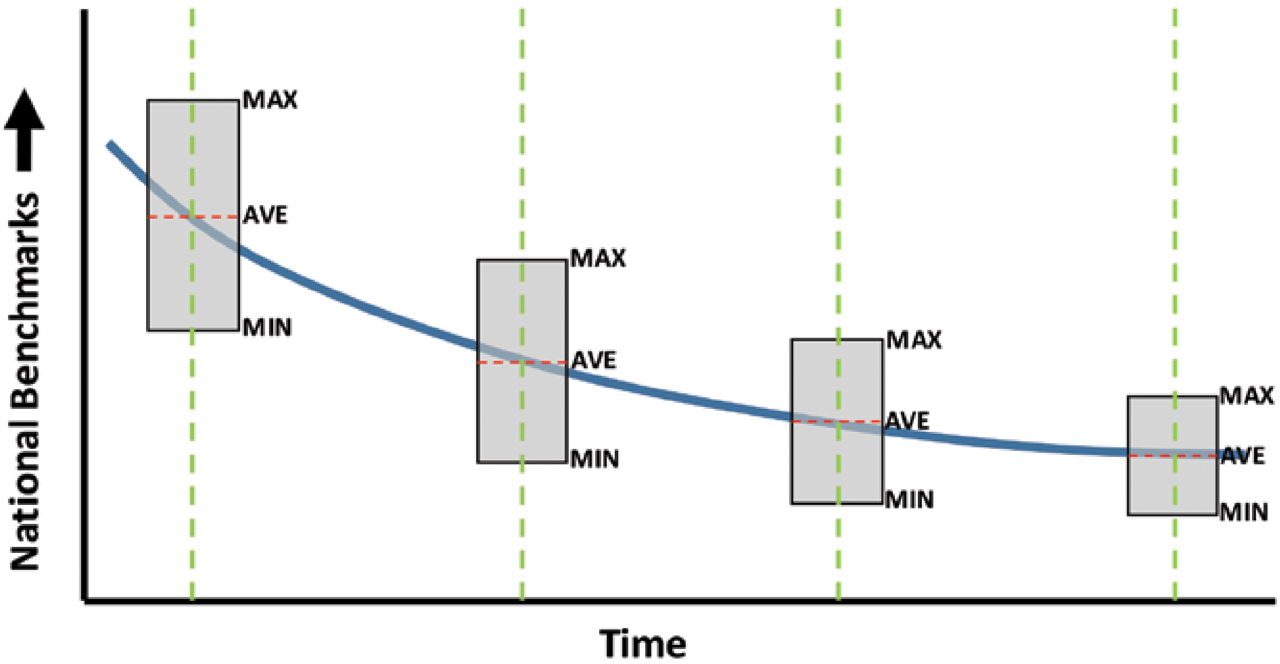

Figure 8: Updating and progression of national WUE benchmarks

There is at this stage, no specific plan with regard to the frequency at which benchmarks would be updated although it would probably be on an annual basis. However, the on-line SWAF would automatically generate the data that would make the updating of benchmarks more easy to implement. The more urgent need is to review the benchmarks for the "other" commodity group, using SWAF data, to publish benchmarks for the different commodity groups, currently combined under "other".

4.5. Amendment of WUE benchmarks to accommodate catchment constraints

The WUE benchmarks that were developed as part of this project for each commodity are considered to be generally valid across South Africa. However, there may be particular stressed catchments where due to significant pressures on the available water resources from a range of water use sectors (not only mining), merely meeting the current benchmarks may result in a higher mining water use than the catchment can accommodate. In such an event, the national benchmarks need to be revised to stricter catchment benchmarks to reflect the availability of water within the catchment and these revised benchmarks will be communicated to the water users by the DWS or relevant CMA. The process to be followed in adjusting the national benchmarks to catchment specific benchmarks is illustrated by way of a hypothetical practical example.

Consider a hypothetical Catchment A where severe water constraints have resulted in a situation where the DWS has determined from its reconciliation strategies that the maximum available water for the mining sector in the catchment is 15 million m^3/annum. This catchment has the following mining activities:

- Coal mining: 25 million ROM tons/annum;
- Platinum mining: 3 million ROM tons/annum; and
- Other mining: 5 million ROM tons/annum.

Based on the data presented in the Benchmarks report, the national benchmarks for consumptive specific water use for the different mining commodities are as follows:

- Coal mining: 0.38 m^3/t;
- Platinum mining: 1.82 m^3/t; and
- Other mining: 0.65 m^3/t.

In this catchment, if all the mines had to meet the current national benchmarks (or continue as is) then the consumptive water use by the mining sector in this catchment would be as follows:

- Coal mining: 25,000,000 t/annum x 0.38 m^3/t = 7,600,000 m^3/annum
- Platinum mining: 3,000,000 t/annum x 1.82 m^3/t = 5,460,000 m^3/annum
- Other mining: 5,000,000 t/annum x 0.65 m^3/t = 3,250,000 m^3/annum

In this hypothetical situation, the total water use by mining would therefore be 16,310,000 m^3/annum which exceeds the hypothetically available water for mining of 15,000,000 m^3/annum by 8.73%, Accordingly, the benchmarks for these commodities need to be reduced by 8.73% to create catchment benchmarks that ensure that mines do not use more than the available water that can be allocated to the mining sector. The revised catchment benchmarks for consumptive specific water use will therefore be equally adjusted downwards by 8.73% to become the following:

- Coal mining: 0.35 m^3/t;
- Platinum mining: 1.66 m^3/t; and
- Other mining: 0.59 m^3/t.

The same principle would apply to other catchments where it may be necessary to tighten benchmarHowever, as South Africa is a water scarce country, the national benchmarks will not be relaxed in catchments that currently have a surplus of water.

5. SPECIFICATION OF GENERIC WC/WDM MEASURES

5.1. Generic Measures Derived From Recent Literature

The processes outlined in this WC/WDM Guideline and the DWS Best Practice Guidelines, will assist mines in identifying and evaluating a variety of site-specific appropriate water conservation measures that take account of the realities on an individual mining site.

The literature review also presented a number of approaches followed by different mines when implementing site-specific WC/WDM plans. In addition, a very relevant paper on WC/WDM in the mining industry was accessed and key findings from this paper are summarised and presented below. The paper in question is titled "Reducing mine water requirements", authored by Gunson, A.J., Klein, B., Veiga, M. and Dunbar, S. and was published in the Journal of Cleaner Production (Vol 21, 2012, pp71-82). Some critical statements made in this paper that are aligned with the approach and philosophy of this project, are the following:

- The high rate of water recycling within the mining industry means that water consumption depends not on the amount of water required for individual unit operations, but on the amount of water lost to permanent water sinks, such as evaporation, seepage or retention in the concentrate or tailings material;
- The first step towards improving or designing mine water systems is to develop a good understanding of the mine's existing system. No effort should be undertaken to improve a mine water system until a reasonably accurate site water balance has been completed;
- Any water management plan should ensure that existing facilities are well run and maintained. Basic steps such as fixing leaky pipes and valves, replacing undersized or worn-out pumps, and improving thickener or clarifier operation can lead to inexpensive and impressive improvements; and
- Better water system design revolves around two key concepts: first, running all processes at the highest solids density possible without negatively impacting the process and, second, supplying all processes with the poorest acceptable quality water, that does not impact process performance.

This paper also divides WC/WDM strategies or measures into 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 waste water being lost from the system by reusing it to replace other new water sources.

5.1.1. Measures to reduce mine water use

Typical measures to reduce mine water use include the following:

- Reducing the contaminated runoff areas on a mine and increasing the clean areas, while allowing clean runoff to enter the natural watercourse;
- Reducing wet area/open area in the tailings storage facility (TSF);
- Reducing fines generation during grinding to lower tailings water retention;
- Improving tailings thickener performance;
- Reducing water losses through thickened tailings or paste tailings disposal;
- Reducing water losses through the installation of drains in the TSF;
- 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;
- Reducing open water evaporation through covers (tanks/thickeners/tailings ponds);

- Reducing evaporation through alternative dust suppressants or additives (on roads, at mining face and in plant);
- Eliminating evaporative cooling;
- Reducing pump gland service water usage;
- Reducing site employee/contractor water use;
- Reducing water consumption through ore pre-concentration or selective mining; and
- Reducing water use through dry processing (avoiding the need for water in any or all of the mining systems).

5.1.2. Measures to reuse mine water

Measures to reuse mine water include the following:

- Collecting and reusing surface runoff water from contaminated areas;
- Reusing mine water pumped from mine workings;
- Reusing cooling water;
- Reusing grey water; and
- Reusing collected tailings seepage and/or pond return water.

5.1.3. Measures to recycle mine water

Measures to recycle mine water include the following:

- Recycling TSF surface water;
- Recycling TSF seepage water;
- Recycling tailings thickener overflow;
- Recycling concentrate or intermediate thickener overflow;
- Recycling potential mine effluent water; and
- Treatment and reuse or recycle any water disposed of or discharged from the mine

5.1.4. Water reduction model

The paper by Gunson, et al (2012) presents the outcome of a water balance simulation model (similar to what is advocated in this document **(see Section 3.1 above**) that was used to simulate a hypothetical low grade copper mine in an arid region, treating 50 000 tons per day of ore, producing a copper concentrate and operating a conventional tailings disposal facility. The model was used to simulate six different scenarios as follows:

Scenario 1 – Base case: In the base case, no effort is undertaken to reduce water evaporation or otherwise lower water consumption beyond reclaiming water from the TSF and the concentrate dewatering processes.

Scenario 2 – Traditional Case with Water Conservation: In Scenario 2, the mine has the same processes and equipment as the traditional case, but has eliminated as many sources of water loss as possible, with a focus on reducing evaporation losses.

Scenario 3 – Paste Tailings Case: In Scenario 3, the mine has installed a 75 m diameter tailings thickener to produce paste, but left everything else as per Scenario 1. All of the flotation tailings flow to the new thickener – the overflow water is pumped to the process water tank and the paste tailings, at 65% solids by mass, is pumped to the TSF.

Scenario 4 – Filtered Tailings Case: In Scenario 4, the mine has installed a 75 m diameter tailings thickener to feed a bank of tailings filters, but with no further change to Scenario 1. All of the flotation tailings flow to the new thickener with the overflow water pumped to the process water tank. The thickened tailings are then filtered to 80% solids by mass, and deposited by a stacker conveyor in the TSF. The filtrate can be reused or recycled.

Scenario 5 – Ore Pre-Sorting Case: In Scenario 5, the mine has installed an ore pre-sorting system after the primary crusher with the purpose of rejecting any ore below a certain grade. This model conservatively assumes that 20% of the ore can be rejected while retaining 98% of the copper. While the mine could increase production to keep the mill running at 50,000 tons/day, for the purposes of comparison, the mine production, in the model, will remain unchanged, dropping the post-sorter mill feed rate to 40,000 tons/day. This would allow much of the mill equipment to be reduced in size. However, for simplicity, the surface area of the flotation cells and the fresh and process water tanks will be unchanged. Pre-sorting may also require an additional crushing step not addressed here.

Scenario 6 – Combined Water Reduction Case: In this final scenario, the water savings options which most reduced water withdrawals in the previous scenarios are combined. The scenario includes the water conservation methods included in scenario 2, the filtered tailings system described in scenario 4, and the ore pre-sorting system described in scenario 5. To summarize the process, the ore is pre-sorted, rejecting 20% of the ore while retaining 98% of the copper, and the flotation tailings are filtered to a solids content of 80% by mass. In addition, an organic binder is applied to the site roads, all site grey water is directed to the process water tank, a fog dust suppression system is installed on the primary crusher dump pocket and the coarse ore stockpile is covered. The concentrate thickener, the water tanks and the flotation cells are covered. Finally, tiles are placed on the tailings thickener to reduce evaporation by 95% and the final concentrate is filtered to 93% solids by mass.

The water use efficiency of the different scenarios were determined with the water balance model and the results are presented in Table 1 below.

Table 1: Scenario Summary

Water Withdrawal	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
m^3/day	37935	32801	29662	15471	31076	9858
m^3/ton ore	0.76	0.66	0.59	0.31	0.62	0.20
m^3/ton copper	157.4	136.1	123.0	64.2	140.9	44.7
% reduction	0	13.5	21.8	59.2	18.2	74.0

This paper by Gunson, et al (2012) clearly demonstrates that the most significant improvements in water use efficiency are obtained when mines start developing and implementing WC/WDM measures that are directed towards reducing water losses to final sinks and that the best results are obtained when a combined and integrated approach is taken.

5.2. Generic Measures Derived From Practical Experience

Years of experience in conducting water management exercises at a variety of mines allows the identification of a range of generic measures that mines can consider when developing their site-specific WC/WDM plans. Not all the listed measures will be applicable at every mine and the benefit in terms of reduced water usage for each measure will vary from mine to mine. Management measures that will have a very significant benefit at one mine may only have limited benefits at other mines or, in some cases, may not even be applicable.

The purpose of the generic measures listed below is to provide the mines with ideas and options that they should consider when developing their site-specific WC/WDM plans. In particular, the potential benefits of each measure should be evaluated using the computerised water balance simulation tool before decisions are made as to whether or not the particular measure can be fruitfully applied or that it would have a positive impact at any mine.

For the purpose of this report, the identified generic measures have been divided into the following categories:

- WC/WDM measures for mining operations;
- WC/WDM measures for ore / mineral processing operations;
- WC/WDM measures for waste, residue disposal and tailings storage operations; and
- General WC/WDM measures.
- The generic measures are listed in the following sections.

5.2.1. WC/WDM measures for mining operations

The following generic measures have been identified:

- Pre-dewatering of areas to be mined with beneficial use of the water derived from the dewatering if water is of such a quality that it is unable to be returned to the environment;
- Mining done to prevent intersection/interconnection to water-bearing strata /aquifers;
- Where intersection of water-bearing strata/aquifers cannot be avoided, ensure that intersected water is protected from quality deterioration and pumped out of the mine workings for beneficial reuse by the mine or an off-site third party;
- Mining done to avoid surface water bodies such as streams, wetlands and dams;
- Old workings sealed off to prevent ingress into active workings;
- Surface waters (streams) diverted around mining impacted areas to limit ingress;
- Ventilation optimised to limit the need for cooling / refrigeration;
- Recycle and re-use water employed for underground drilling equipment and mining machines;
- Backfill underground workings to reduce water ingress and cooling requirements, provided water quality aspects have been adequately considered and investigated;
- Separate & divert surface water which may enter the opencast pit workings (clean and dirty water separation);
- Close and rehabilitate opencast and open pit workings in such a way as to limit recharge/ingress to the workings and return run-off to the environment;
- Backfill and rehabilitate final voids and pit lakes to evaporation losses;
- Accelerate the disturbed land rehabilitation and reduce the backlog of rehabilitation behind the active mining face/operation;
- Reduce the operational surface footprint of the mine – smaller shaft areas, minimal spoil piles, less roads, compact plant design;
- Reduce the amount of haul roads to a minimum and use dust suppressants, thereby reducing the amount of water required for dust;
- Employ dry cooling systems on underground mine working/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, thereby making the water easier to reuse;
- Mine water reticulation systems – leak detection systems; and
- Mine open water dams – evaporation controls (covers) and seepage control/liners.

5.2.2. WC/WDM measures for ore / mineral processing operations

The following generic measures have been identified:

- Employ dry beneficiation technologies where feasible instead of wet processing;
- Employ dry ROM/ore conveyance (such as conveyer belts) methods rather than hydraulic conveyance systems (such as slurry pipelines);
- Minimize footprint of ROM and ore stockpiling to reduce contaminated water production;
- Place product stockpiles under dry covers so they shed water and do not collect and contaminate storm water that would require collection afterwards;
- Employ high solids content/consistency processes for ore/mineral beneficiation;
- Recover water from the ore and minerals products and recycle to the minerals processing plant;
- Recover water from the waste and tailings and recycle to the ore/minerals processing plant;
- Employ dry cooling technologies rather than evaporative cooling systems;
- Reduce fines component in the plant – fines typically retain more water;
- Improved thickener performance and water recovery;
- Leak and overflow detection systems;
- Dam level auto-controls;
- Dry wash down and spillage clean-up;
- Ore/minerals processing plant footprint minimized to reduce the generation of contaminated water;
- Plant spills/overflows captured as close as possible to the point of origin of the spillage and recycled to the ore/minerals plant water circuits;
- Clear separation of process spillage systems from storm water systems to allow collection of process spillages close to the point of origin for direct reuse and collection of storm water for general reuse within the plant area;
- Product stockpile footprint areas minimized to reduce impacted water production;
- Water storage in underground compartments to reduce evaporative losses;
- Water supply and storage managed by aquifer recharge and abstraction to reduce evaporative losses;
- Process water intake based on hierarchy to preferentially use mine impacted water and reduce intake of fresh water; and
- Development and adherence to water quality standards for all water users in the beneficiation plant that aims to provide all users with the worst possible quality water that does not affect process performance or cause corrosion/scaling problems (Fit-for-purpose water approach).

5.2.3. WC/WDM measures for waste, residue disposal and tailings storage operations

The following generic measures have been identified:

- 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 & pit workings to reduce the surface footprint of waste/residue disposal facilities – this has two benefits – 1) less surface area for storm water contamination and 2) assists with the free drainage of the pit once rehabilitated and hence the reduced ingress of water into the pit itself, after having taken due consideration and having evaluated potential impacts on water quality;
- 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;
- 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;
- Collect and intercept seepage from residues and tailings disposal facilities for reuse and recycling;
- Manage water balance on return water dams to ensure that no water enters the return water dams that was not included in the original sizing and design of these dams (i.e. this will generally mean that storm water runoff and water from mining operations should not be stored in tailings return water dams);
- Keep evaporation dams empty; and
- Design all return water dams with small surface areas or with evaporative covers and liners to prevent seepage losses.

5.2.4. General WC/WDM measures

The following generic measures have been identified:

- Replace all conventional or external water supply sources and/or resources with any “excess water” discharged from the mine, (treated or untreated);
- Supply excess water that cannot be accommodated within the mine’s water balance (with or without treatment) to external, off-mine water users;
- Discharge excess water that cannot be accommodated within the mine’s water balance, in compliance with regulatory discharge standards, to streams & rivers for downstream water users. i.e. do not hold excess, provided that all external supply sources to the mine have been replaced;
- Water use by staff & personnel using a range of water savings devices and methods:
    - Low volume closets, taps and showers; and
    - Waterless urinals, etc.
- Development of non-conventional water resources to reduce the use of conventional surface and groundwater resources:
    - Reclaimed AMD; and
    - Covers on dams & ponds.
- Incorporate water conservation and demand management training into standard induction programmes for all employees and contractors – training and awareness programmes;
- Incident response and reporting times regarding water losses; and
- Incorporate adherence to WC/WDM targets into the KPIs of key staff on mines that have responsibility for ensuring that WC/WDM is optimally developed and implemented on mines.

5.3. Concluding remarks regarding generic measures

The most significant improvements in WUE performance indicators are obtained when the mine addresses losses at the **key final water sinks** such as pollution control dams and the tailings disposal facilities where losses to discharge, evaporation and seepage need to be minimised in order to improve specific water use.

Losses to evaporation can be minimised by reducing the volumes of water (e.g. by thickening of tailings prior to disposal) reporting to facilities where evaporation takes place (e.g. tailings disposal facilities), reducing the surface area of water pools or covering open water pools.

Seepage can be prevented by lining of facilities, or alternatively seepage from existing facilities such as tailings disposal facilities which were not lined can be intercepted and recycled after appropriate treatment.

All discharge streams should be evaluated with the view towards recycling these streams, with or without treatment, back into the mine's water balance in order to replace and or eliminate cleaner input streams. The biggest sinks to be addressed generically are as follows:

- Evaporation;
- Seepage; and
- Discharges to permanent mine storage e.g. underground workings

The results reported in literature and practical experience, indicate that addressing these water losses from the system can result in very significant improvements in WUE performance. The South African mining industry which is currently primarily focused on reducing potable water use and replacing this with alternative water sources needs to consider the abovementioned types of interventions if it is to make significant strides in improving its WUE indicators.

6. CASE STUDY: A PRACTICAL GUIDE FOR COMPILATION AND DEVELOPMENT OF A COMPREHENSIVE WC/WDM PLAN

The procedures described in this report, specifically those included in Chapter 3, are best demonstrated by way of a case study. The case study presented here is for a platinum mine that is similar to one of the platinum mines included in the site surveys. It must be emphasized that the case study represents an application and an outcome of the methodology that is unique to the specific mine and that a different case study would have different outcomes. It must also be emphasized that the case study application is not a blueprint that can necessarily be generically applied to all other mines, although the same procedures and principles would apply. The tool used for the assessment and presentation of the case study is the generic water balance model which is described in detail in the Benchmarks report.

The generic water balance model developed for this project does have simulation capability and therefore complies with the recommendation for water balances to have simulation capabilities and is therefore considered suitable to demonstrate the methodology described in this report.

6.1. Context of the Case Study Mine

In reviewing and understanding the relevance of the case study, it is necessary to be able to place the case study mine into the correct context within the mining industry and specifically within the context of the variables listed in the variables matrix. The case study mine had the following characteristics:

- Rainfall – 650 mm/annum;
- Evaporation – 1400 mm/annum;
- Groundwater regime – wet with groundwater make of 0.8 m^3/ton ROM;
- Commodity mined – platinum;
- Type of mining – underground;
- Depth of mining – 600m;
- No mine cooling;
- Ore processing – limited to concentrator with no ore smelting on site;
- Presence of sulphides – yes, but no AMD due to excess of neutralising minerals;
- Age of mine – 15 years;
- Remaining life of mine – 25 years;
- Regional hydraulic interactions – not considered;
- Quality of fresh water – good (RWB and ground water);
- Type of tailings disposal – conventional (98 ha) with tailings disposed at 1.40 SG;
- Geographic size of operations – 894 ha;
- Type of beneficiation – conventional concentrator;
- Workforce on mine – 3100 persons; and
- Water use / worker / day – 200 l/day (workers with access to showers), 120 l/day (day workers not using showers).

6.2. Construction of the Mine Water Balance

For a normal mine situation, the water balance would be developed in accordance with the methodology set out in BPG G2. For this case study, the generic water balance model (Figure 9) described in detail in the Benchmarks report was used. The input parameters for the generic water balance model were adjusted during the calibration process to ensure that the simulated water balance closely represented the actual case study mine water balance. The resultant summary water balance is shown in Figure 9 below while the water balance flow diagram is shown in Figure 10.

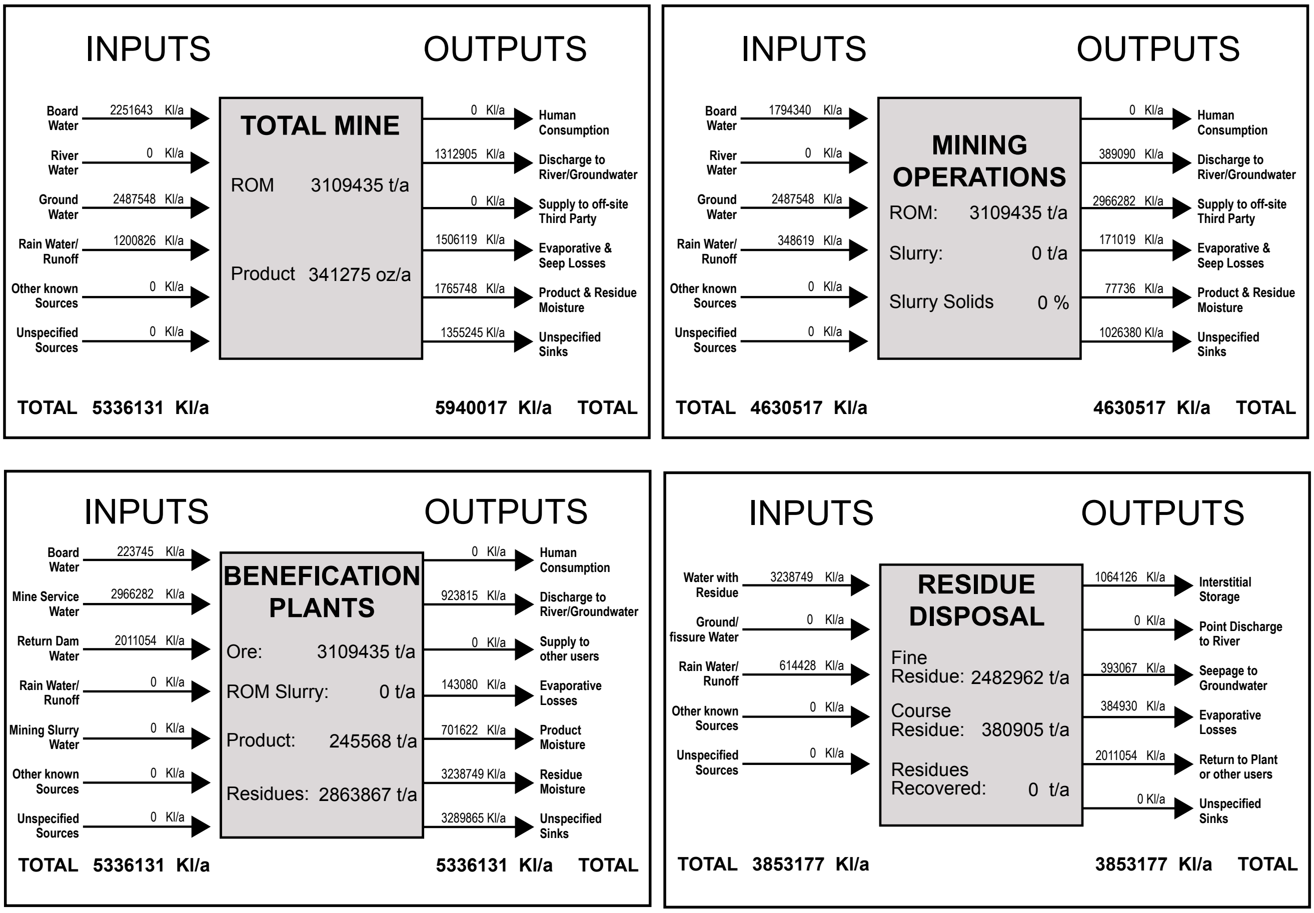

Figure 9: Case Study Water Balance

The only component not shown above is the relatively minor "other" uses that include the offices, change rooms, etc.

6.3. Development of the WC/WDM Plan

The case study was developed in accordance with the step-wise procedure shown in Figure 6 above.

6.3.1. Determine current WUE indicator values for the mine

The current WC/WDM status of the mine can be determined with respect to the different WUE indicators as listed in **Section 3.2.1 above**, with these indicators being calculated as described in the Benchmarks report.

Based on the calibrated water balance program, the major water uses for various sections of the mine are summarised in Table 2 below. The various consumptive water uses per individual area are given in Table 3

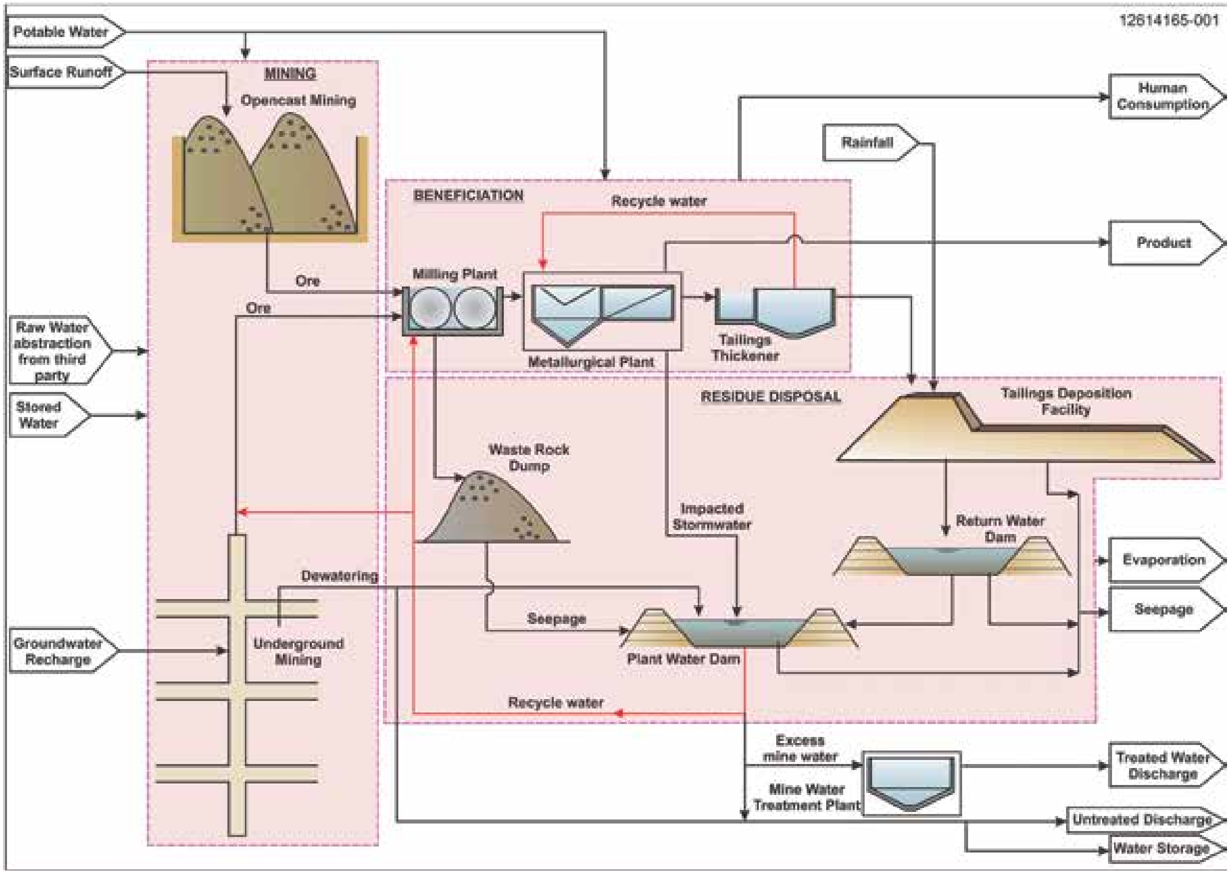

Figure 10: Case study water balance flow diagram/ schematic

Table 2: Water use indicators for the case study mine

Description	Units	Mining	Beneficiation	Residue Disposal	Other Activities	Total Mine
Total water input	m³/year	4,630,500	5,336,100	3,853,100	315,900	5,940,000
Total consumptive use	m³/year	1,586,500	2,097,400	1,940,200	315,900	5,940,000
Total specific water use per ROM ton	m³/t	1.49	1.72	1.24	0.10	1.91
Consumptive specific water use per ROM ton	m³/t	0.51	0.67	0.62	0.10	1.91
Percentage wastewater not reused	%	51%	47%	100%	100%	60%
Water recycle ratio	%	34%	45%	0%	0%	66%

For example: the residue disposal section includes the tailings storage facility (TSF) and the return water dam (RWD) (all included within the TSF). Internally within the residue disposal section, there is no recycling of water, although water is recovered from the residue disposal section and reused in the beneficiation section. When only considering the residue disposal section, this flow is defined as an outflow since it leaves the residue disposal area and not a recycle (since it does not come back to the residue disposal block). When considering the entire mining operation, (the "Total mine column" in Table 2) the water that is recycled from the residue disposal to the beneficiation is defined as a recycle in terms of the total mining operation as it does not exit the total mine water balance.

Table 3: Consumptive water usage of case study mine evaluated

Description	Units	Mining	Beneficiation	Residue Disposal	Other Activities	Total Mine
Unspecified sinks	m^3/t	0.33	0.11	0.00	0.00	0.44
Total water discharged (untreated)	m^3/t	0.13	0.30	0.00	0.00	0.42
Seepage/Evaporation losses	m^3/t	0.06	0.05	0.25	0.00	0.35
Interstitial storage	m^3/t	0.00	0.00	0.34	0.00	0.34
Water out in product	m^3/t	0.00	0.23	0.00	0.00	0.23
Dust suppression	m^3/t	0.00	0.00	0.06	0.00	0.06
Treated sewage discharged	m^3/t	0.00	0.00	0.04	0.00	0.04

Although all the indicators have not been calculated in this study, mines should include all indicators expressed in the required units such as volumes of water discharged, stored, etc in m^3/day. The WUE indicators calculated for the case study mine in its current situation/state, could now be compared to the national benchmark values as presented in the Benchmarks report that is reproduced as Table 4 below, with the case study values shown in the last column.

Table 4: National WUE benchmarks and ranges for platinum mines

Platinum Mining	Units	Benchmark	Min (1x σ)	Max (1x σ)	Case Study
Total Mine					
Total Mine - Total water input per ROM ton	m^3/t	1.85	1.64	2.07	1.91
Total Mine - Consumptive use per ROM ton	m^3/t	1.82	1.60	2.04	1.91
Total Mine - % waste water not recycled	%	65%	42%	78%	54%
Total Mine - Water recycle ratio	%	39%	2%	76%	40%
Mining					
Mining - Total water input per ROM ton	m^3/t	1.22	1.12	1.33	1.49
Mining - Consumptive use per ROM ton	m^3/t	0.46	0.36	0.56	0.51
Beneficiation					
Beneficiation - Total water input per ROM ton	m^3/t	1.46	1.19	1.74	1.72
Beneficiation - Consumptive use per ROM ton	m^3/t	1.46	1.46	1.46	0.67
Residue Disposal					
Residue Disposal - Total water input per ROM ton	m^3/t	1.92	1.59	2.25	1.24
Residue Disposal - Consumptive use per ROM ton	m^3/t	1.08	0.89	1.28	0.62

Evaluation of the data shown in Table 4 above clearly indicates that the case study mine is currently performing on par with the current WUE benchmark values and that there is room for improvement in the WUE. The data also indicates that primary areas where WUE is above the WUE benchmark values is for total water input/ ton mined in the mining section – this is primarily due to high groundwater make into the mining area (See highlighted figures in Table 2). The consumptive water use per ton mined is, however, within the benchmark range – illustrating the value of the consumptive water use indicators compared to the total water use indicators. WUE data for the case study mine also exceeds the benchmark values for total specific water usage in the residue disposal section, although consumptive specific water usage is well within the WUE benchmarks when the recycling of RWD water back to the beneficiation plant is taken into account.

Key conclusions to be drawn from an analysis of Table 4 and Figure 9 above are as follows:

- The mine's WC/WDM plan should be pro-active and aim to get well below the average WUE benchmarks for all sections with the view towards providing security of water supply by demonstrating a commitment to optimum WUE. This approach needs to be viewed against the reality that water supply is scarce within the case study mine's water supply area, with multiple competing demands for the limited water resource. It is also anticipated that WUE benchmarks will become more stringent in future and by maximising its WUE status, the case study mine would provide for improved security of water supply to the mine should there be future water restrictions and/or water reallocations;
- The mine should aim to find ways to reduce total water input per ton mined within the mining circuit by reducing the high imported "Board Water" consumption and replacing this with ground water, also addressing water losses to unspecified sinks through increased reuse and recycling of this water; and
- The mine should aim to find ways to reduce total water input per ton mined within the beneficiation plant circuits by reducing the high Board water consumption and replacing this with other water sources and also addressing water losses to unspecified sinks through enhanced reuse and recycling of this water that is currently being lost.

6.3.2. Identify a range of potential WC/WDM measures

Chapter 5 of this report lists a range of measures that could be considered by a mine. However, the options listed in Chapter 5 are not exhaustive and additional measures should also be identified. Conversely, these options will not always be applicable to every mine. The options presented in Chapter 5.2 of this report have been considered below, in terms of their potential application to the case study mine, while in reality other options could also be considered, as already mentioned.

6.3.2.1. Potential WC/WDM measures for mining operations

The following generic measures have been identified:

- Pre-dewatering of areas to be mined with beneficial use of the water derived from the dewatering – due to the deep mining undertaken, this option is not considered practical and is not considered for this case study;
- Mining done to prevent intersection/interconnection to water-bearing strata /aquifers – insufficient information is available for the case study mine to determine the practical feasibility of this option and it was therefore not considered here;
- Where intersection of water-bearing strata/aquifers cannot be avoided, ensure that intersected water is protected from quality deterioration and pumped out of the mine workings for beneficial reuse – **this is a potentially feasible option for the case study mine, except that the water is only reused and recycled when it reaches the surface – captured in Option 13;**
- Mining done to avoid surface water bodies such as streams, wetlands and dams – this is not applicable to the deep mining operations at the case study mine;
- Old workings sealed off to prevent ingress into active workings – this is already happening at the case study mine;
- Surface waters (streams) diverted around mining impacted areas to limit ingress – not applicable to the deep mining operations at the case study mine;
- Ventilation optimised to limit the need for cooling / refrigeration – no mine cooling is undertaken at this mine;
- Recycle and re-use water employed for underground drilling equipment and mining machines – **consider the use of rock drills that utilise less water than conventional drills – see Option 7;**
- Backfill underground workings to reduce water ingress and cooling requirements – no backfilling operations at this mine and no detailed information available to consider in this case study;

- Separate & divert surface water which may enter the opencast pit workings (clean and dirty water separation) – not applicable as there are no opencast workings;
- Close & rehabilitate opencast & pit workings and rehabilitate to limit recharge/ingress to the workings – not applicable as there are no opencast workings;
- Rehabilitate and shape to free drain the rehabilitated land to reduce runoff to opencast workings & pits – not applicable as there are no opencast workings;
- Backfill and rehabilitate final voids and pit lakes to evaporation losses – not applicable as there are no opencast workings;
- Upgrade standard & quality of mined land rehabilitation to reduce water ingress/ infiltration – not applicable as there are no opencast workings;
- Accelerate the disturbed land rehabilitation and reduce the backlog of rehabilitation behind the active mining face/operation – not applicable as there are no opencast workings;
- Recycle and re-use mine dewatering for other applications (ore processing, minerals beneficiation, etc.) – **this is considered and included in Option 13;**
- Employ dry cooling systems on underground mine working/refrigeration circuits, rather than evaporative cooling – not applicable as there is no mine cooling at this mine; and
- Minimise contact time between water and ore in the mining operations in order to reduce water quality deterioration, thereby making the water easier to reuse – not considered as there is insufficient information available to consider water quality aspects in the generic mine water model.

6.3.2.2. <u>Potential WC/WDM measures for ore/mineral processing operations</u>

The following generic measures have been identified for inclusion in the case study:

- Employ dry ROM/ore conveyance methods (such as conveyer belts) rather than hydraulic conveyance systems – this is already in place at the case study mine;
- Minimize footprint of ROM and ore stockpiling to reduce contaminated/impacted water production/generation – no significant ore stockpiling occurs at the case study mine;
- Employ high solids content/consistency processes for ore/mineral beneficiation – not considered as part of this case study;
- Recover water from the ore and minerals products and recycle to the minerals processing plant – **this is included as Option 9;**
- Recover water from the waste and tailings and recycle to the ore/minerals processing plant – **this is included in option 8;**
- Employ dry cooling technologies rather than evaporative cooling systems – not considered for this case study due to insufficient information;
- Ore/minerals processing plant footprint minimized to reduce contaminated/impacted water generation – no information on current footprint size of beneficiation plant and therefore did not consider this option;
- Plant spills/overflows captured as close as possible to the point of origin of the spillage and recycled to the ore/minerals plant water circuits – requires detailed information for the plant which was unavailable for the case study mine;
- Clear separation of process spillage systems from storm water systems to allow collection of process spillages close to the point of origin for direct reuse and collection of storm water for general reuse within the plant area - requires detailed information for the plant which was unavailable for the case study mine;
- Product stockpile footprint areas minimized to reduce impacted water production – already applied at the case study mine;

- Water storage in underground compartments to reduce evaporative losses – not applicable at this mine as there are no underground storage compartments isolated from underground mining activities;
- Water supply and storage managed by aquifer recharge and abstraction to reduce evaporative losses – not considered as too little information for the case study;
- Process water intake based on hierarchy to preferentially use mine impacted water and reduce intake of fresh water – **this is considered and incorporated into Option 13;** and
- Development and adherence to water quality standards for all water users in the beneficiation plant that aims to provide all users with the worst possible quality water that does not affect process performance or cause corrosion/scaling problems – **will be implemented as part of Option 13.**

6.3.2.3. Potential WC/WDM measures for waste, residue disposal and tailings storage operations

The following generic measures have been identified for inclusion in the case study:

- Dispose of waste in underground workings (backfill) to reduce the surface footprint of waste/residue disposal facilities after due consideration of impacts on water quality – not applicable to the type of mining practiced at this mine;
- Dispose of waste in old opencast & pit workings to reduce the surface footprint of waste/residue disposal facilities – not applicable as this is not an opencast mine;
- Thicken and/or dewater residues and tailings to limit the amount of water disposed with the residues and tailings – **this is considered in Option 8**;
- Reduce the amount of water stored on the residue/tailings disposal facilities to reduce evaporative losses – **considered as part of Option 5**;
- Reduce the surface area of the free water pool on tailings storage facilities to recue evaporative losses – **considered as part of Option 5**;
- Collect and intercept seepage from residues and tailings disposal facilities for reuse and recycling – **considered as part of Options 4, 6 and 13;** and
- Manage water balance on return water dams to ensure that no water enters the return water dams that was not included in the original sizing and design of these dams (i.e. this will generally mean that storm water runoff and water from mining operations should not be stored in tailings return water dams) – this is already implemented at the case study mine.

6.3.2.4. Potential general WC/WDM measures

The following generic measures have been identified for inclusion in the case study:

- Implement dry dust control measures (such as binding agents on haul roads) to reduce water use – **considered as part of Option 10;**
- Supply excess water that cannot be accommodated within the mine's water balance (with or without treatment) to external, off-mine water users – not applicable at this mine as there are no suitable off-mine water users;
- Discharge excess water that cannot be accommodated within the mine's water balance, in compliance with regulatory discharge standards, to streams & rivers for downstream water users – not considered – rather apply Option 13 to treat and reuse the water;
- Water use by staff & personnel using a range of water savings devices and methods – **this is considered in Option 11:**
  - Low volume closets; and
  - Waterless urinals, etc.
- Development of non-conventional water resources to reduce the use of conventional surface and

groundwater resources – none of these options are applicable at the case study mine:

  - Rain harvesting;
  - Reclaimed AMD; and
  - Covers on dams & ponds.

- Incorporate water conservation and demand management training into standard induction programmes for all employees and contractors – **this is incorporated into Option 3;** and
- Incorporate meeting of WC/WDM targets into the KPIs of key staff on the mines that have responsibility for ensuring that WC/WDM is optimally developed and implemented on mines will be implemented but cannot be simulated in the mine water balance – **this is included in Option 3**.

6.3.2.5. *<u>WC/WDM options identified for the case study</u>*

The following generic measures have been identified for inclusion in the case study:

After considering all possible options, 14 potential WC/WDM measures were identified as listed in Table 5 below. These options can be divided into three broad groups as follows:

- Options to reduce consumptive water use;
- Options to reuse / reclaim water; and
- Options to use alternative operational technologies that will save water.

The potential options for the case study have also been classified into the above categories and more information on each is provided in the sections below.

Identify Opportunities to Reduce Consumptive Water Uses

During this step, each consumptive water use was evaluated and opportunities were identified to reduce that particular consumptive use.

Unspecified sinks

Water lost through unspecified sinks could indicate an inadequate water balance. Some of this water may be recoverable for reuse in the process. Since the unspecified sinks for this mine represent a substantial volume of water, it is recommended that the water balance be upgraded in order to identify the unspecified water sinks (**Option 1**). Once this is done, opportunities to reduce this water usage can be formulated.

Unspecified sinks could partially be attributed to leaks in the water system, or inappropriate use (wastage) of water. One of the water conservation opportunities for this mine could therefore be to develop a systematic program to check and repair leaks in the water system (**Option 2**). An additional opportunity will be to develop and roll out an education and awareness programme on the proper use of water and the importance of saving water in order to reduce water wastage (**Option 3**). Management procedures can also be implemented to monitor and manage water usage. Wastage of water can then be managed through performance reviews of responsible managers. This may require the installation of additional measurement and monitoring systems to improve management and accounting of water.

Total water discharged (untreated)

For this mine, a substantial volume of water is discharged to the environment, while raw water is imported for the operation. Replacement of imported raw water with excess discharged water therefore seems to be a substantial opportunity and will be discussed in a later section. If all excess water cannot be recycled, treatment of the excess water will be required to meet the appropriate standards to allow this water to be provided to a potential off-site third party user (**Option 4**).

Seepage/Evaporation losses

The bulk of the seepage and evaporation losses for the case study mine are attributed to the residue disposal section (tailings facility, return water dam and other surface dams).

The evaporation and seepage losses at the tailings facility, return water dam and other surface dams can be reduced by reducing the surface area of the tailings pool and the surface area of the dams. This can be achieved through improved operational management of the dams to ensure that the pool area is kept to a minimum at all times (**Option 5**). Automatic control systems can be installed to improve the operation.

Seepage through the tailings facility, return water dam and other surface dams can be reduced by lining the dams (**Option 6**). Seepage and evaporative losses in the mining section (underground) is attributed to water lost with ventilation in the underground areas. For this case study mine, a large portion of the water used underground is used by the rock drills, where some of the water is then later lost through evaporation. A potential opportunity could therefore be to convert to rock drills that use less water (**Option 7**) if such technology is available.

Interstitial storage

A substantial amount of water is trapped in the tailings residue remaining on the tailings facilities (interstitial storage). An opportunity to address this is to decrease the water content of the tailings, using for example high density thickening or paste technology (**Option 8**). This will at the same time reduce the water lost through seepage and evaporation, since paste residue will not have a pool on the paste tailings facility.

Water out in product

The product of this case study mine is a dilute concentrate from the flotation process containing a substantial volume of water. This water is in effect lost to the mine through transportation with the product to the smelter/refinery. An opportunity for this mine could be to thicken the product in order to recover some water from the product for reuse in the process (**Option 9**). Note that this will only result in an overall water saving if the water in the product is not required in the downstream processes. If the water is required in the downstream processes, it will increase the downstream process water requirement and will add to the water use. Contaminated water that was removed by the thickening process will therefore probably be replaced with a better quality water and not provide an overall water saving.

Dust suppression

A relatively small amount of water is used for dust suppression by this mine. An option that can be considered to reduce this water usage is the use of dust binding agents on the haul roads in order to reduce the water requirement for dust suppression (**Option 10**).

Treated sewage water discharged

The volume of treated sewage water that is discharged can be reduced by implementing water conservation measures such as low-flow shower heads in change rooms, low water usage toilets, etc. (**Option 11**). Alternatively, the water can be suitably treated for reuse in the mining process (**Option 12**), such as tailings transport, dust suppression, etc.

Reduce Total Raw Water Import through Recycle/Reuse

Since a substantial volume of water is imported and discharged by this mine, the most significant opportunity will be to treat and reuse the discharged water in order to reduce the raw water imported. Most of the process water used in the mining and beneficiation process can be replaced by the water that is currently being discharged with little or no treatment required (**Option 13**). The discharges are however seasonal, which will require the construction of suitable reservoirs/dams to store the water during the rainy season for reuse in the dry season. It will also require the installation of pumps and pipelines and modifications to the existing reticulation system in order to transport the excess water to the required demand points.

Recycling surplus water to be treated and used as potable water could also be a theoretical opportunity on this mine (**Option 14**). This will however require the construction of a water treatment plant to treat the water to potable standards.

Identify Methods to Reduce Water Usage through Technology Replacement

Some technology replacement options, such as using different rock drills, converting to paste technology, etc. have already been discussed in previous sections. No additional technology replacement options have been identified for this case study mine.

Table 5: Assumptions made to estimate saving of each option

No	Option	Basis of Calculations
1	Upgrade water balance – identify & implement opportunities	25% of unspecified sinks saved through measures identified after upgrading water balance.
2	Repair leaks	25% of unspecified sinks saved by repairing leaks.
3	Water management and awareness programme	10% of unspecified sinks saved by reducing water wastage
4	Intercept and treat all untreated discharges	80% of surplus water discharged to the river can successfully be intercepted & treated.
5	Minimise pool and surface areas of all dams	Pool on tailings facility reduced by 80%, & surface area of return water dam and other surface dams reduced by 50%.
6	Lining of all dams to reduce seepage	Seepage from all dams reduced to zero by lining.
7	Change to rock drills that use less water	Water used for mining reduced by 25%.
8	Convert tailings to paste	SG of tailings increased from 1.4 to 1.82.
9	Thicken product (prior to export to smelter)	SG of product increased to 1,2 to 1.4.
10	Reduce dust suppression	Water used for dust suppression decreased by 75%.
11	Water conservation measures to reduce sanitation water	Water used per person reduced by 40%.
12	Treat and reuse sanitation water	All sanitation water treated and reused.
13	Reuse surplus water for process water	80% of surplus water discharged to river intercepted, treated and reused as process water.
14	Reuse surplus water for potable water	Since all available surplus water can be used for process water, there will not be enough surplus water for this opportunity. This opportunity will therefore not be an option.

6.3.3. Evaluate each option using the simulation water balance model

The water balance program was used to estimate the expected water saving if each identified opportunity is implemented individually. The assumptions shown in Table 5 were made in calculating the water saving of each opportunity (as noted previously, these assumptions may not all be realistic or relevant, but are used only for indicative purposes in this case study). The Basis for Calculation is illustrative for this case study and will have to be assessed on an individual mine's situation, age of infrastructure, mining methods, remaining LoM, etc. Certain opportunities, such as converting tailings to paste, thickening of product, etc are based on design data and experience. Detailed studies will have to be undertaken by the mine when developing its WC/WDM plan.

The results are shown in the table below. From the results it is clear that the largest single water saving can be achieved by reusing the surplus water as process water and terminating the import of external water from the "Water Board" for processing. The indicated potential savings allow prioritisation and selection of potential opportunities. Implementing the individual savings will impact on the potential saving achievable by implementing other savings. (The sum of the individual savings exceeds the total saving if all opportunities are implemented).

Table 6: Calculated water saving per option

Description		Total water input			Consumptive use		
Units		**m³/year**	**m³/t**	**% Saving**	**m³/year**	**m³/t**	**% Saving**
Current Situation		5,940,000	1.91		5,940,000	1.91	
Option							
1	Upgrade water balance – identify & implement opportunities	5,706,500	1.84	3.9%	5,706,500	1.84	3.9%
2	Repair leaks	5,706,500	1.84	3.9%	5,706,500	1.84	3.9%
3	Water management and awareness programme	5,804,500	1.87	2.3%	5,804,500	1.87	2.3%
4	Treat all untreated discharges and provide to off-site third party	5,940,000	1.91	0.0%	4,889,700	1.57	17.7%
5	Minimise pool areas of all dams	5,702,100	1.83	4.0%	5,702,100	1.83	4.0%
6	Lining of all dams to reduce seepage	5,707,800	1.84	3.9%	5,707,800	1.84	3.9%
7	Change to rock drills that use less water	5,920,500	1.90	0.3%	5,920,500	1.90	0.3%
8	Convert tailings to paste thickened tailings	5,700,000	1.83	4.0%	5,700,000	1.83	4.0%
9	Thicken product	5,706,500	1.84	3.9%	5,706,500	1.84	3.9%
10	Reduce dust suppression	5,803,800	1.87	2.3%	5,803,800	1.87	2.3%
11	Water conservation measures to reduce sanitation water	5,906,400	1.90	0.6%	5,906,400	1.90	0.6%
12	Treat and reuse sanitation water	5,813,200	1.87	2.1%	5,813,200	1.87	2.1%
13	Reuse surplus water for process water	4,889,700	1.57	17.7%	4,889,700	1.57	17.7%
14	Reuse surplus water for potable water	5,940,000	1.91	0.0%	5,940,000	1.91	0.0%

6.3.4. Determine the life cycle capital and operating costs for each option

Budget level NPV calculations have been undertaken for each of the different options and they have been broadly classed as low, medium and high as shown in Table 7 below.

Table 7: Budget cost estimates for each option

No	Option	NPV Cost Estimate (R million)
1	Upgrade water balance – identify & implement opportunities	**3.5**
2	Repair leaks	**6.5**
3	Water management and awareness programme	**0.5**
4	Treat all untreated discharges	**50.0**
5	Minimise pool and surface areas of all dams	**15.0**
6	Lining of all dams to reduce seepage	**3.0**
7	Change to rock drills that use less water	**10.0**
8	Convert tailings to paste	**70.0**
9	Thicken product (prior to export to smelter)	**25.0**

No	Option	NPV Cost Estimate (R million)
10	Reduce dust suppression	**5.0**
11	Water conservation measures to reduce sanitation water	**1.0**
12	Treat and reuse sanitation water	**5.0**
13	Reuse surplus water for process water	**12.0**
14	Reuse surplus water for potable water	**50.0**

In the above table, NPVs highlighted in green are classed as low cost, yellow as medium cost and blue as high cost.

6.3.5. Rank all options

All options that have been simulated and for which cost estimates (as Net Present Value) have been determined should be entered into a tabular format including information as set out in Section 3.2.5 to enable ranking of options. It is also recommended that the risk and sustainability of the different options also be included in the ranking process. The riskiest options are generally those that rely on people and behaviour for their success, then come the engineered prevention or management systems while the most robust options are those that are based on avoidance. For the purpose of this hypothetical case study, the ranking shown in Table 8 below was based on cost effectiveness measured as R per m^3 consumptive water use saved per annum. In a real-life WC/WDM plan, the effect of the various options on the other WUE indicators should also be considered, as should the risk and sustainability of the options.

Cumulative water savings that may be realised vs cost required to implement the opportunities are reflected in Figure 11. Treating excess water for process use (recycle) was selected rather than the treatment of excess water for either potable use or supply to an off-site third party. While the case study and Figure 11 assumes that all the savings can be accumulated, it must be cautioned that this is not a universally correct assumption as some implemented options may preclude the application of other options. The recommended practice, therefore, is to model each cumulative management option (for all the indicators) to determine what the actual net savings would be and to plot the outcome of such simulations against cumulative cost when deriving graphics for all the indicators such as is shown in Figure 11.

Table 8: Ranking of options

Description		Consumptive WUE Indicator			Capex	Cost Effectiveness	Ranking
Option		m^3/year	m^3/t	% Saving	R x 10^6	R/m^3/annum saved	
Current Situation		5,940,000	1.91				
1	Upgrade water balance – identify & implement opportunities	5,706,500	1.84	3.9%	3.5	14.99	3
2	Repair leaks	5,706,500	1.84	3.9%	6.5	27.83	4
3	Water management and awareness programme	5,804,500	1.87	2.3%	0.5	3.69	1
4	Treat all untreated discharges	5,940,000	1.91	0.0%	50.0	-	14
5	Minimise pool areas of all dams	5,702,100	1.83	4.0%	15.0	63.05	9
6	Lining of all dams to reduce seepage	5,707,800	1.84	3.9%	3.0	12.92	2
7	Change to rock drills that use less water	5,920,500	1.90	0.3%	10.0	514.56	12
8	Convert tailings to paste thickened tailings	5,700,000	1.83	4.0%	70.0	291.73	11
9	Thicken product	5,706,500	1.84	3.9%	25.0	107.04	10

Description		Consumptive WUE Indicator			Capex	Cost Effectiveness	Ranking
10	Reduce dust suppression	5,803,800	1.87	2.3%	5.0	36.71	6
11	Water conservation measures to reduce sanitation water	5,906,400	1.90	0.6%	1.0	29.78	5
12	Treat and reuse sanitation water	5,813,200	1.87	2.1%	5.0	39.41	7
13	Reuse surplus water for process water	4,889,700	1.57	17.7%	12.0	47.60	8
14	Reuse surplus water for potable water	5,940,000	1.91	0.0%	50.0	-	13

Figure 11 also shows that 80% of the potential improvement in WUE is obtained after spending only 34% of the capital cost of all the WC/WDM options identified. This clearly demonstrates that mines can achieve considerable improvements in their WUE with considerable water savings in the short to medium term (low hanging fruit) before having to allocate budgets to the relatively more expensive options to further improve their WUE indicators. Significant capital investments will be required to achieve the last 20% of the potential improvement in WUE.

For the sake of simplicity and to illustrate the concept, this exercise has only been done for the consumptive specific water use for this case study. In a real life WC/WDM plan, a similar exercise should be undertaken for all the WUE indicators before a final decision is made on which management options to include in the WC/WDM plan.

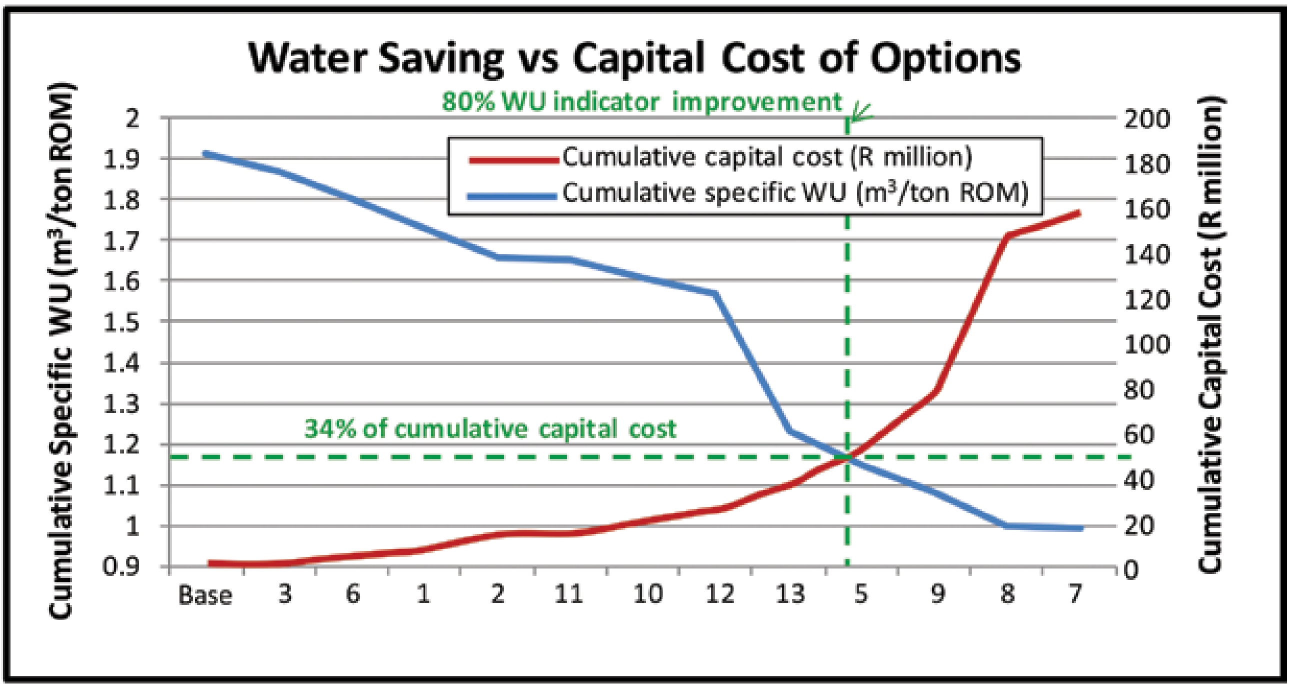

Figure 11: Cumulative cost to implement opportunities vs savings in water use

6.3.6. Select combination of options for integrated 5-year WC/WDM plan

Based on the results of the ranking exercise, an integrated 5-year WC/WDM plan can be developed that incorporates short, medium and long-term elements as follows:

- Short term: Within the next 2 years;
- Medium term: Within the next 5 years; and
- Long term: Within the next 6 to 10 years (Options that will carry through into the next 5-year WC/WDM plan).

Three opportunities are selected as an example for this case study. More opportunities could be added if required.

Based on the results calculated in Section 6.3.4 and 6.3.5 above, it is recommended that the major focus should be on re-using the surplus water as process water (Option 13). Although this option is only ranked number 8 in Table 8 below based on cost effectiveness, it has the ability to effect the greatest overall improvement in WUE in an area where water supply is under severe stress, and the mine decided that implementation of this option would therefore provide the greatest security of water supply. The costs and timing for this option will depend on the quality, location and storage requirements. These factors will have to be taken into account when deciding on the roll-out of this option. When this option is implemented, Option 4 (treatment of the untreated discharges) will become irrelevant. Based on the results of this case study it is recommended that work commence immediately to investigate and plan Option13, and that it is rolled out over the short, medium and long terms based on the time needed for detailed planning, procurement, construction, etc.

Upgrading of the water balance may potentially lead to a substantial saving, as well as repairing leaks (Options 1 & 2). These two options will be relatively simple and can be implemented at low cost and in the short term (25% reduction of unspecified sinks) and medium term (40% reduction of unspecified sinks).

Minimising the pool areas (Option 5) can also lead to a substantial saving. It is recommended that an automated control system be implemented to ensure that pool areas are kept at a minimum. This can be rolled out in the medium term. If this option is successful, it will reduce the savings that can be achieved by converting to paste technology. Since the conversion to paste technology will be expensive, justifying this based on water savings only will probably not be feasible.

Implementing the selected four options (1, 2, 5 and 13) over the short, medium and long term should result in a cumulative saving for the next ten years as shown in the figure below. By year ten, the consumptive specific water use of this mine can be reduced from 1.91 m^3/t to 1.50 m^3/t by implementing these 4 options (22% saving from the current situation). This prediction can therefore be used to define the WUE indicator targets for this mine over the next 5 to 7 years while further options could be investigated to further improve the plan or develop the full next 5-year plan (up to 10 years).

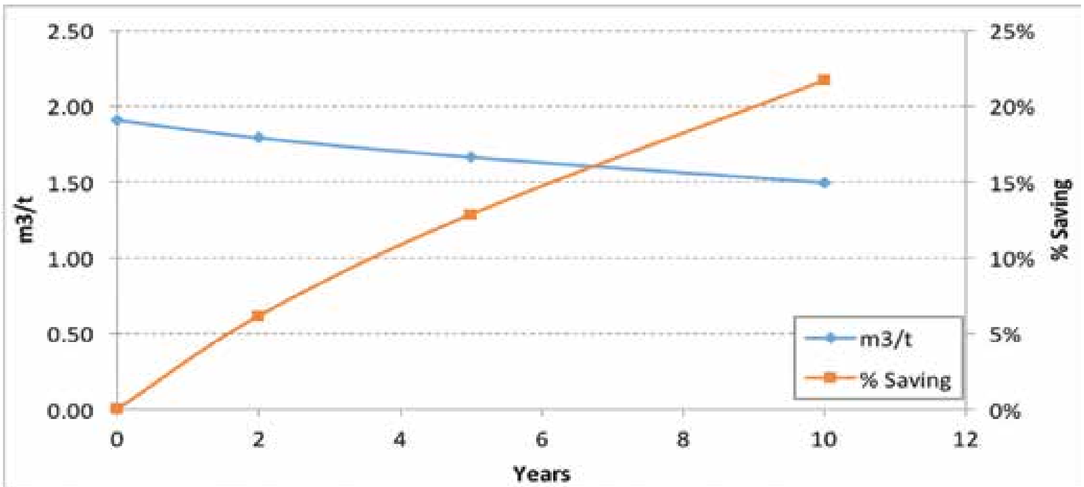

Figure 12: Cumulative saving of the four major opportunities over the next 10 years

The total mine raw water import reduces from 0.72 m^3/t to 0.31 m^3/t over the assessed 10 year period, a reduction of 57%, as illustrated in Figure 13.

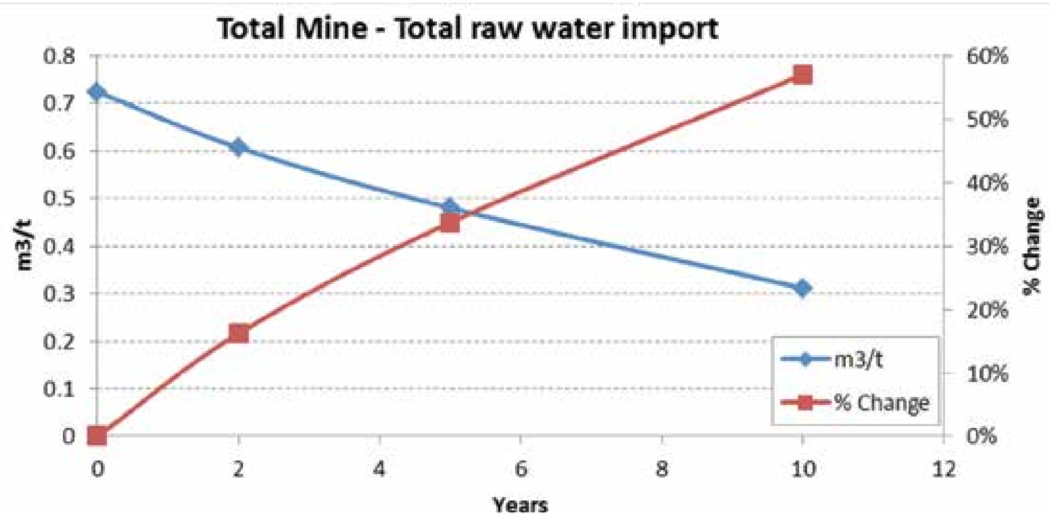

Figure 13: Saving in raw water import due to implementation of the four opportunities over the next 10 years

The savings in combined water losses, defined as seepage plus evaporation losses, is shown in Figure 14 and the saving in water lost to unspecified sinks is shown in Figure 15.

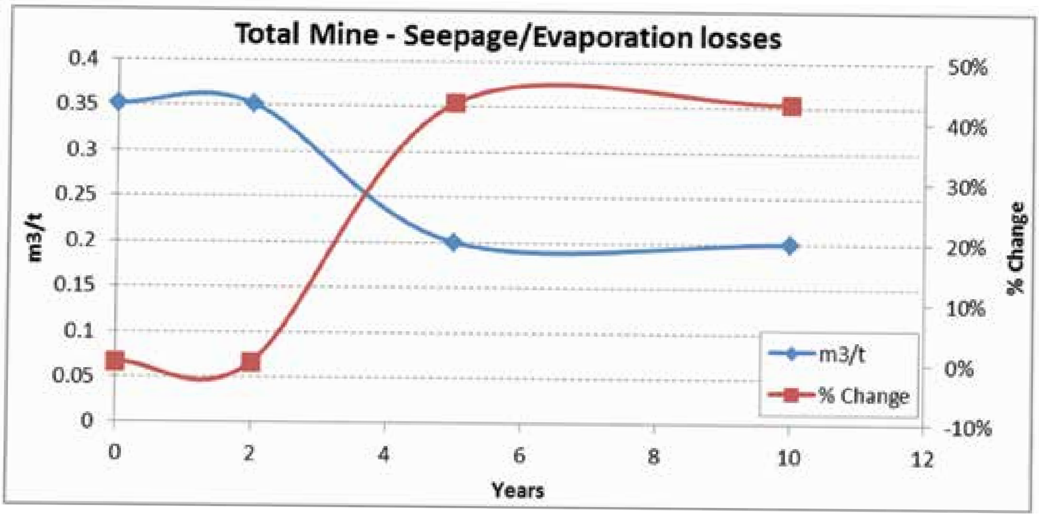

Figure 14: Saving in water losses due to implementation of the four opportunities over the next 10 years

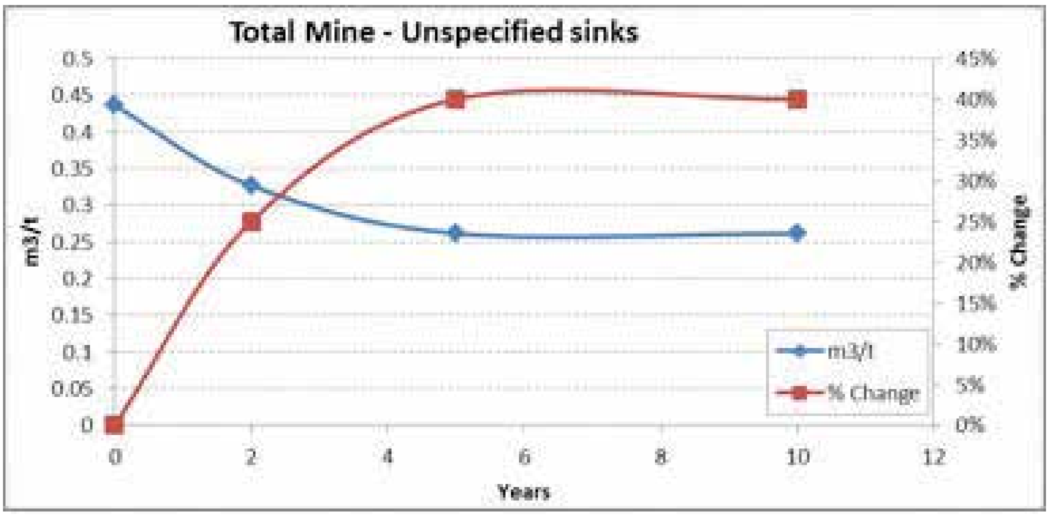

Figure 15: Saving in water lost to unspecified sinks due to implementation of the four opportunities over the next 10 years

The information described above must then be utilised to develop, motivate and document a comprehensive WC/WDM plan to be submitted to DWS for approval.

While the calculations can be undertaken for all the different WU indicators, the integrated WC/WDM plan developed for this case study mine could have the following targets for consumptive specific water use for the next 5 years (with a projected target for 10 years also included (although it is feasible that the 4 steps could rather be implemented over 6 to 7 years):

Year 1: 1.85 m^3/ton

Year 2: 1.79 m^3/ton

Year 3: 1.75 m^3/ton

Year 4: 1.70 m^3/ton

Year 5: 1.66 m^3/ton

Year 10: 1.49 m^3/ton

6.3.7. Evaluate adequacy of proposed 5-year WC/WDM plan

The annual targets for each of the WUE indicators could be compared to the national benchmark values that apply at the time when the plan is being developed. While the same exercise needs to be undertaken for each of the WUE indicators, the case study demonstrates the principle by way of having used the consumptive specific water use. The progressive improvement in consumptive specific water use over the proposed 5-year term of the WC/WDM plan from the current 1.91 m^3/ton down to 1.66 m^3/ton, is below the current benchmark of 1.82 m^3/ton and there is therefore no need to consult with DWS to obtain approval to submit a WC/WDM plan with WUE targets that exceed the benchmarks. However, as mentioned previously, the on-line SWAF will determine the rating and ranking of the case study mine's WC/WDM plan to determine how it compares with other WC/WDM plans for mines in the same commodity group and/or in the same water management area.

6.3.8. Compile and submit a 5-year WC/WDM plan

Once the mine has moved through the activities described above, the mine will need to prepare a documented WC/WDM plan. The initial 5-year WC/WDM plan will be submitted by the mine as an addendum to its existing IWWMP (for those mines that have already compiled and submitted an IWWMP to the DWS). Future updates of the WC/WDM plan would have to be incorporated into and synchronised with updates to the mine's IWWMP.

7. CONCLUSION

This report provides a simple yet practical and comprehensive WC/WDM implementation methodology that clearly defines the separate responsibilities of the mining industry and DWS. This methodology is based on the generic implementation methodology presented and agreed to in Phase 1 of the report. Additionally, the report provides a strong recommendation as to why the work undertaken by the Minerals Council of Australia in the form of the Water Accounting Framework (WAF) should be adopted, with certain modifications, to also provide the reporting framework for WC/WDM in South Africa.

A clear and practical methodology is presented that will assist the mines in moving from their current WUE situation to a much improved future situation where they have developed and implemented WC/WDM plans that would bring them to well below the current WUE benchmarks. The report also presents a clear case study that demonstrates the principles included in the methodology proposed in this report for the development of a WC/WDM plan and the development of mine-specific WUE targets.

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APPENDIX A
WATER ACCOUNTING FRAMEWORK - AUSTRALIA

A1 DISCUSSION OF AUSTRALIAN WATER ACCOUNTING FRAMEWORK

The Water Accounting Framework (WAF) was developed by the Minerals Council of Australia as a means to enable mines to measure, record and report water information in a consistent manner. The WAF also distinguishes between water accounting and water reporting. Accounting concerns the consolidation of water balance information, as discussed throughout the framework description. Reporting concerns the presentation of water balance information in formats tailored to the needs of various reporting uses and users. The WAF aims to provide a 'one-stop-shop' for water information, but it must be remembered that it is **not** the tool for managing water and does not replace the water balance.

The MCA Water Accounting Framework provides:

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

The Water Accounting Framework produces the following four reports:

1. The **Input-Output Statement** lists flows for all input and output categories and diversions, with their associated water quality category, for the reporting period, along with the change in storage.
2. **Statement of Operational Efficiencies** lists the total flows into the tasks, volume of reused water, reuse efficiency, the volume of recycled water and recycling efficiency.
3. The **Accuracy Statement** lists the percentage of flows that were measured, simulated and estimated.
4. **Contextual Information** ensures that numbers in the report are not divorced from the context in which a facility is operating. It gives background information about the water resources of the operational facility as well as any conditions that have an impact on the management of those water resources such as climate information, information about the water resources of the region and the catchment in which the sites are located.

Mines that subscribe to the WAF are expected to, inter alia, undertake the following:

1. Alignment of company water metrics consistent with the Water Accounting Framework Input-Output Model.
2. Alignment of company water quality descriptors consistent with the Water Accounting Framework.
3. Using the framework definitions and metrics to satisfy existing public reporting (company reporting or similar) on company aggregated water inputs and outputs and quality. Reporting requirements could include reporting on volumes against the Global Reporting Initiative.

Full implementation guidance on the water accounting framework and an Input-Output Model Excel Workbook Template can be found at http://www.minerals.org.au/focus/sustainable development/water accounting

A description of what these commitments entails is provided below.

A1.1. Alignment of Company water metrics consistent with the Water Accounting Framework Input-Output Model.

Of primary importance to the alignment of company water metrics is the adoption of the four Source and five Destination categories provided within the framework. These include:

- **Sources:** Surface Water, Groundwater, Sea Water and Third Party Water; and
- **Destinations:** Surface Water, Groundwater, Sea Water, Supply to Third Party and Other.

Full definitions for each of the above categories are provided within the Framework Guidance (Section 2.2.1).

While a list of individual inputs and outputs, which form subsets of the Source and Destination categories, have been provided within the Framework guidance, these are not prescriptive and can be removed, modified or new categories added depending on the specific needs of a company or operation.

Along with the standard definitions, standard units should be adopted; Mega-litres (ML) have been adopted for the purposes of the framework.

A1.2. Alignment of company water quality descriptors consistent with the Water Accounting Framework

Water quality is an important component of the water accounting framework and the goal of consistent reporting and communication of water use. The framework provides three categories of water. These include:

Category 1: Water is of a high quality and may require minimal and inexpensive treatment (for example disinfection and pond settlement of solids) to raise the quality to appropriate drinking water standards.

Category 2: Water is of a medium quality with individual constituents encompassing a wide range of values. It would require moderate level of treatment such as disinfection, neutralisation, removal of solids and chemicals to meet appropriate drinking water standards.

Category 3: Water is of a low quality with individual constituents encompassing high values of total dissolved solids, elevated levels of dissolved metals or extreme levels of pH. It would require significant treatment to remove dissolved solids and metals, neutralise and disinfect to meet appropriate drinking water standards.

To satisfy this commitment, companies should align their generic water quality categories with the three categories provided above. A list of water quality parameter ‘thresholds’ and a decision tree is provided in the User Guide (Section 2.4) to enable companies to select the appropriate water quality category.

A1.3. Annual public reporting (Company Reporting or similar) on company aggregated water inputs and outputs using the framework definitions and metrics

To promote communication and transparency of minerals industry water use, MCA member Companies are asked to use the water accounting framework to meet their annual public water reporting needs at an aggregated company level. To satisfy this commitment, companies should use the framework to meet any of its existing public water reporting requirements (such as annual sustainability or performance reporting or similar).

Accordingly, companies may use the framework to respond to Global Reporting Initiative (GRI) reporting requirements for EN8 – Total Water Withdrawn by Source, and EN21 – Total Water discharged by Quality and Destination. Methods on how to use the framework to satisfy GRI reporting requirements are provided both within the Water Accounting Framework User Guide (Section 6.1) and the User Template provided.

A2: APPLICABILITY OF AUSTRALIAN WAF TO SOUTH AFRICAN WC/WDM

A detailed review of the Minerals Council of Australia WAF (MCA WAF) leads to the conclusion that the system that they developed is directly applicable to the South African situation and that this approach would serve as a critical supporting framework for the implementation of WC/WDM in the mining industry. A significant amount of work and thought has gone into the development of the MCA WAF and there is little benefit to be derived from re-inventing the wheel in this regard. The MCA WAF succeeds in presenting a simplified yet sufficiently complex framework for a uniform and consistent definition of water use, water discharge and water diversions that will allow all mines to report their water information in a uniform and directly comparable manner. There would need to be some minor modification of the categories to ensure direct applicability for all South African mines.

The MCA WAF also provides a sensible approach to categorising water quality into 3 classes and this approach can also be adopted, with modification to reflect South African national water quality concerns, for use in South Africa. The objective of categorising water into quality classes is to indicate which water falls into a category that can generally be reused without any treatment, which water would require only basic treatment before being recycled and which water falls into a category that would require extensive treatment before recycling. This information would provide a good overview indication of the reuse and recycling opportunities at the mine.

The approach of indicating the confidence class of the different water balance values in terms of whether they are measured, calculated or estimated is also very useful and might benefit from a fourth category - modelled - to distinguish between those values that derive from mathematical modelling (such as runoff) and those that derive from calculation to make inflows and outflows balance for a given unit process.

The MCA WAF will also need to be modified to allow for the calculation of the South African key WUE indicators as opposed to the Australian indicators. Finally, the ability of both the WAF and SWAF to also provide output data in a format that supports GRI reporting conventions is also useful and should be retained for those companies who do subscribe to this practice.

The MCA WAF tool should also be modified to allow for the incorporation of contextual information that is relevant to the WC/WDM information requirements. This could include data such as mining commodity, catchment (preferably quaternary level) and operational data that describes the parameters covered in the Variables Matrix and the Generic Water Balance Model (see Benchmarks report).

A summary of the key characteristics of the MCA WAF is provided in Appendix B and will be used in developing the on-line SWAF system for South African conditions.

A key and critical benefit of adopting the MCA WAF system (modified for South African conditions as described above) is that it will provide annually updated values for the different WUE indicators for South African mines. This is critical to enable the WUE benchmarks to be updated in future and is also the best way to ensure that water balance and WUE data are reported by all mines in a consistent manner. Access to this type of data is also required to enable the current mining commodity category of "other" to be subdivided into a range of more meaningful commodities, each with their own more relevant WUE benchmarks.

A3: A QUICK REFERENCE GUIDE TO THE AUSTRALIAN WATER ACCOUNTING FRAMEWORK INPUT-OUTPUT MODEL OVERVIEW

The minerals industry water accounting framework provides a consistent methodology for the communication of how an operational facility interacts with water. This methodology is based on the consistent representation of these water interactions, as shown in the figure below:

(1) Inputs represent the receipt of water to the operational facility;

(2) Outputs represent the removal of water from the operational facility;

(3) Diversion represents water that is moved around or through the operational facility; and

(4) The task-treat-store cycle represents what an operational facility does with its water and how it stores it.

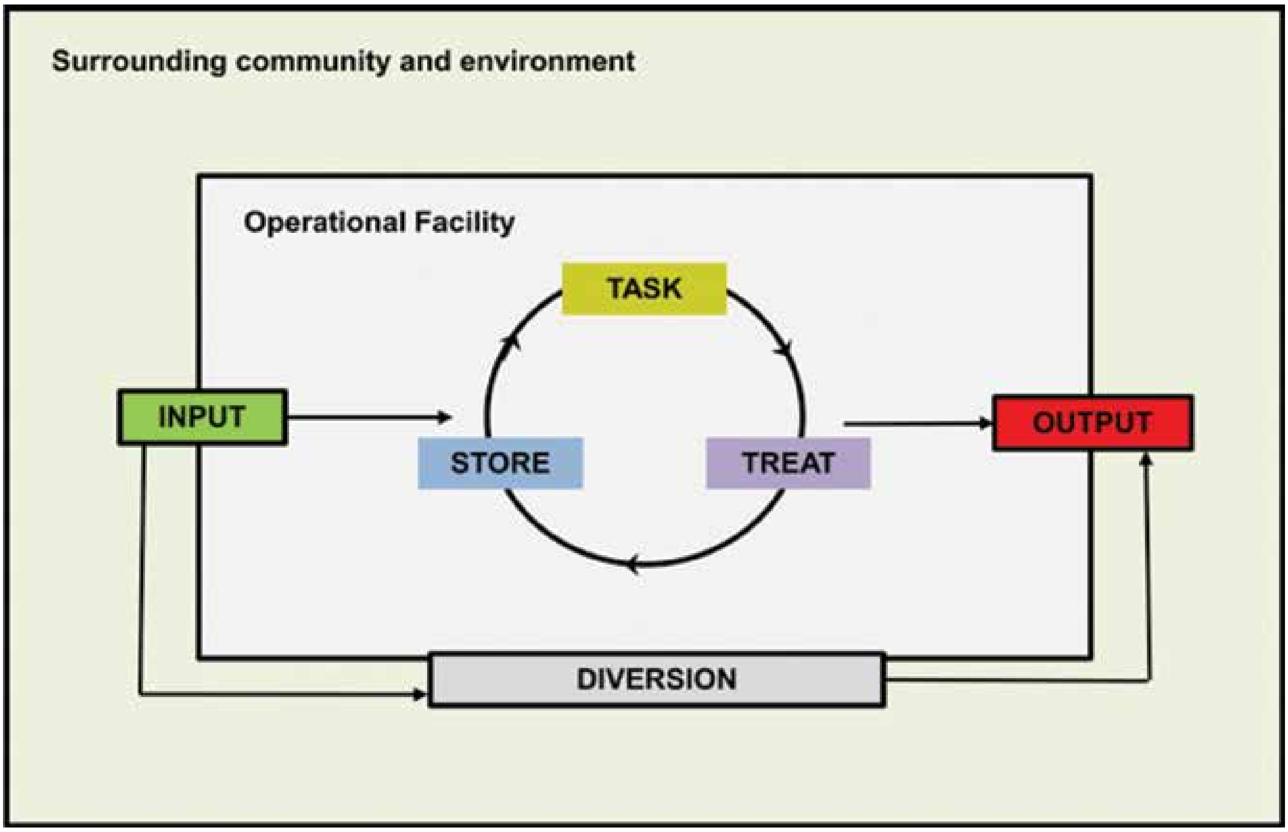


Figure A1 - Consistent representation of the water system of an operational facility

The **Input-Output** model represents the intersection of the facility with the surrounding environment and community. The Input-Output model is a consistent method for reporting a facility's water balance. It lists all inputs by source and all outputs by destination. The Input-Output model does not introduce any new concepts, it simply proposes a consistent way of communicating the water information that most mining companies and operational facilities already collect.

Key information required for the input-Output Model includes:

• Flow volumes into and out of the operational facility by source and destination.

• Diversion flow volumes 'around' the operational facility by source and destination.

• Water quality categorisation of flows (based on framework descriptors).

• Assignment of flow accuracy, based upon water accounting framework methodology.

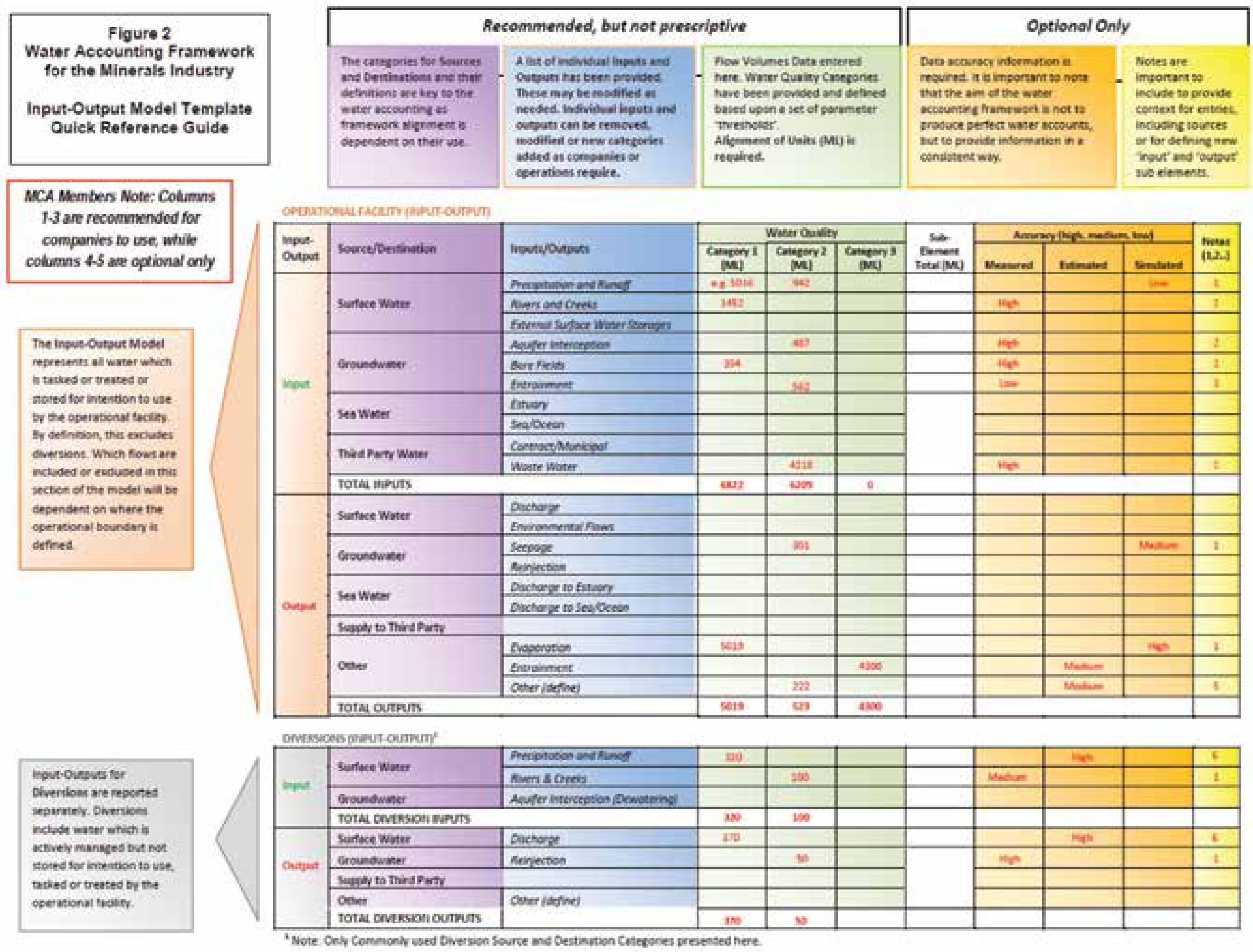
• 'Material' or account relevant information provided through a Contextual Statement and accompanying Notes.

The second component of the water accounting framework is the **Operational Model**, which is a consistent method for the calculation and reporting of water reuse and recycling (store, treat and task cycle within an operation). Given the extensive capacity building required by companies, adoption of the operational model is optional for MCA member companies.

Further Guidance

Framework Guidance and an Input-Output Model Template is available at http://www.minerals.org.au/focus/sustainable_development/water_accounting

For information, a quick reference guide on how to use the water accounting framework input-output model, based upon the format provided in the framework template has been provided in the following **Figure 2.**



APPENDIX B
VARIABLES MATRIX

B1: Introduction

The extent to which water conservation (WC) and water demand management (WDM) measures can be successfully implemented at a mine, is dependent on a number of external and internal variables (differentiating factors). Some of these variables are inherent features of the mine and cannot be changed, while others can be changed through the application of management and operational actions. In the process of developing water use targets and practical approaches to implement WC/WDM to meet these targets, knowledge of these variables is critical. The existence of these variables is also the reason why the setting of targets for WC/WDM in the mining sector cannot be undertaken on the basis of a “one size fits all” approach - different targets must be developed for different mining operations in the sector.

In order to develop defensible, practical and achievable water use benchmarks, it is important to be able to identify the variables that have an effect thereon and to differentiate mines on the basis of these variables. To this end, it is proposed to classify the variables that have a potential effect on water use benchmarks into the following four classes:

- CLASS 1: Variables that characterise the mine’s operations and are difficult to change (especially for existing mines, might be easier to address on new mine) and that have a limiting effect on the extent to which specific water use can be achieved on a mine. These variables should be explicitly considered when setting differentiated water use targets and benchmarks.
- CLASS 2: Variables or practices that influence the mine’s current water conservation status but that can be changed with considerable planning, effort and/or capital expenditure. There is significant justification in considering these variables as valid inputs to the process of setting water use targets, especially with regard to timeframes that are allowed for the mines to converge towards improvement upon the commodity benchmarks.
- CLASS 3: Variables or practices that influence the mine’s current water conservation status but that can be changed without much effort and/or capital expenditure. These variables influence the WC/WDM status of the mining but should not be considered as variables that have much influence on the water use targets to be set.
- CLASS 4: Variables that are often the driving forces for development and implementation of WC/WDM at mines, but which do not influence the differential setting of water use targets.

B2 Presentation of Variables

The following list of variables shown in Tables B1 - B4 (classified in terms of Classes 1 to 4) were identified as having a bearing on the implementation of WC/WDM in the mining sector or having an influence on what the water use target for a mine should be. Data on these variables therefore needed to be captured during the site visits. These variables are also shown in Figure B1, together with the inter-relationship between variables in Class 1 and Class 2.

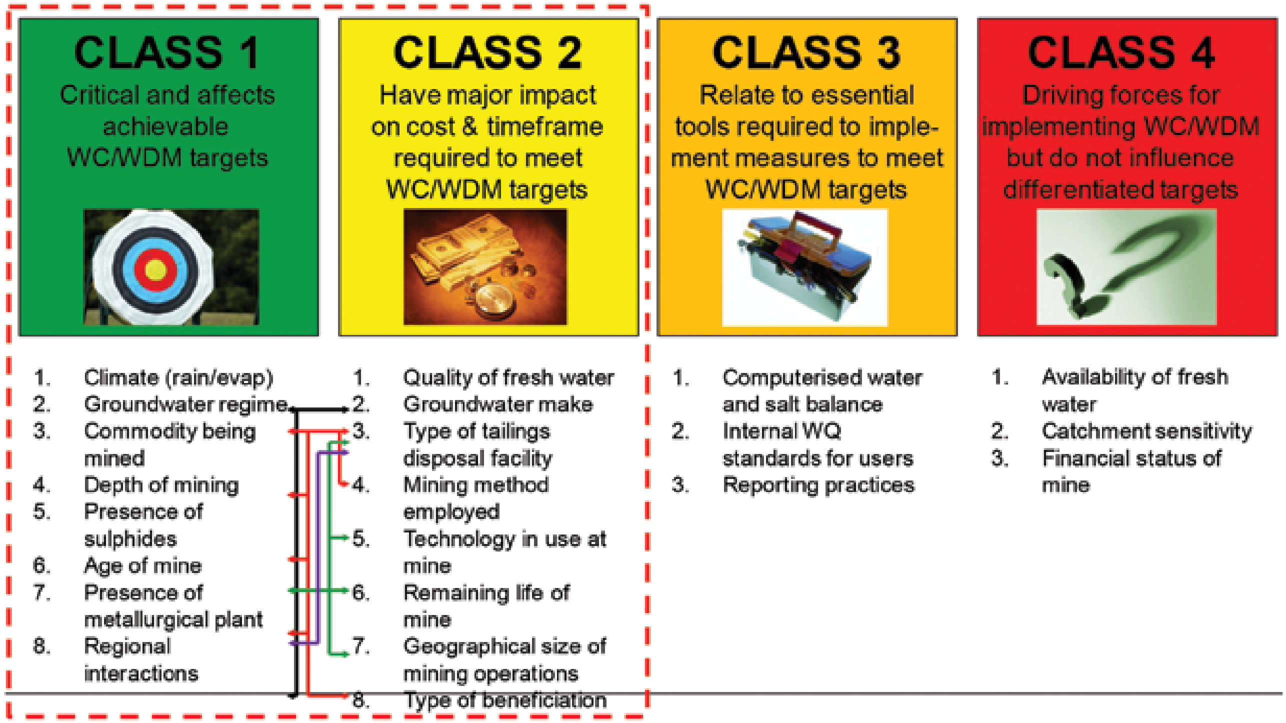


Figure B1: Variables affecting WC/WDM

Table B1: Class 1 Variables - Characterise the mine's operations

Variable Description	Comment
Climate (rainfall and evaporation)	A mine located in a high rainfall area may have significant inputs related to runoff into the mine water balance. Depending on how effective the mine's storm water management is, this may result in significant volumes of contaminated water that need to be accommodated in the WC/WDM plan. Conversely, mines in very arid areas will have very little runoff and will be much more dependent on external fresh water sources such as rivers, groundwater, etc. Furthermore, mines located in areas with very high evaporation rates will have a much greater need to import fresh water to counteract the effects of water loss through evaporation. Such mines may also benefit from focusing WC/WDM actions on minimising surface area of water containment facilities. Although the rainfall and evaporation rates cannot be changed, the impact can be managed through proper WC/WDM methods/technologies.
Groundwater regime in area where mine is located	A mine located in an area with abundant groundwater resources can expect to have groundwater inflows contributing significantly to the overall water balance. While some actions can be implemented to limit ingress of groundwater into the mine workings, none of these would be entirely effective and high groundwater inflows can be expected for these mines. In certain cases, such as mines in the dolomitic regions, the volume of groundwater entering the mine can become the defining factor in the mine's water management system with significant challenges in preventing this water from becoming contaminated. However, if this water is used efficiently within the mining operations, it will limit the need for additional water intake as well as reduce excessive discharges (unless the external water intake of the mine is already zero).
Commodity being mined	Previous research and work done in implementing WC/WDM in the mining industry clearly indicated that there are significant differences in water use and water management challenges between different mineral/metals commodities. Some commodities such as coal are relatively shallow and are produced at very large tonnages, while other commodities such as gold and platinum are mined at great depth with lower ore extraction rates. However, within a certain commodity, various steps can be taken to improve specific water use.

Variable Description	Comment
Extent of mine cooling required	The extent of mine cooling required is strongly correlated with the depth of mining, local geothermal gradient and age of mine. Mines that operate at depth such as gold and platinum have elevated underground temperatures and mine cooling is critical. In such mines, the cooling circuits often represent the largest single user/consumer of fresh water and such mines will have an inherently larger requirement for water than mines that have little or no mine cooling requirement. Water consumption for mine cooling is also dependent on the quality of the fresh water available for the cooling systems, although the water can be treated to mitigate this problem. By treating the water, reductions in intake of water can be achieved.
Presence of sulphide or other reactive minerals in the ore body being mined	Ore bodies that contain sulphides or other reactive minerals will result in water quality deterioration regardless of management measures to control the pyrite oxidation processes. While the water quality deterioration can be managed and controlled by the development and application of effective water management, some degree of water quality deterioration is inevitable. Mine ore bodies with sulphides or other reactive minerals will therefore have to incur greater cost in reducing water usage than mines that do not have such reactive minerals.
Age of Mine	The age of a mine has a number of effects on water usage and WC/WDM. Firstly, old mines are more likely to have been designed without taking into consideration the optimisation / minimisation of water and energy usage. Changing this could incur significant capital cost, which could make it uneconomical if the mine has limited remaining life over which the capital investment can be recovered. Secondly, old mines may be deeper and require more extensive water reticulation and cooling systems with concomitant rising water demand. Thirdly, older mines may have spread out over time, covering a wider geographical area with greater difficulties in implementing infrastructural changes often required in the implementation of WC/WDM measures.
Presence of a hydrometallurgical plant	The presence of a hydrometallurgical plant is strongly correlated with the commodity being mined. Many commodities require the inclusion of a hydrometallurgical plant in order to recover/extract/refine the product. An example of an exception is a coal mine that has a contract to supply coal for Eskom and where little beneficiation of the run of mine product is required. However, various improvements to beneficiation technologies can be applied to improve specific water use.
Regional interactions	Sections of the mining sector are characterised by mines located adjacent to each other. Often only narrow boundary pillars of questionable integrity separate adjacent mines. In such instances, the WC/WDM strategy of any mine can be influenced and affected by water-related activities at the adjacent mine. These problems take on an even greater complexity when adjacent mines fall in the abandoned and ownerless category. Managing these factors is possible, but might require a regional and combined effort.

Table B2: Class 2 Variables – Considerable effort to implement WC/WDM

Variable Description	Comment
Groundwater make into the mine	The volume of groundwater entering the mine is firstly determined by the Class 1 variable - groundwater regime. However, the extent to which groundwater enters the mine workings, can be controlled to some extent by actions undertaken by the mine. Groundwater control measures may include the following: • Grouting of water bearing textures; • Interception of groundwater by dewatering boreholes on the periphery of the mine workings; • Interception of groundwater flows close to the point where they enter the mine workings; • Isolation from mine service water circuits; and • Priority pumping out of mine workings before contamination can occur. Application of these groundwater control measures can provide good quality water to be re-used in the mine water circuits with limited or no treatment thereby reducing the need for additional water intake.
Quality of fresh intake water	Mines that have significant mine cooling requirements and which are located in areas where the fresh water quality is poor, will experience a disadvantage when it comes to reducing fresh water intake. Cooling circuits lose water through evaporation and this causes the salinity of the water to increase with each cycle of concentration. All cooling circuits have a maximum allowable water salinity as determined by corrosion and scaling considerations. High fresh intake water salinity will lead to reductions in the cycles of concentration that can be applied before water must be blown down and replaced with fresh water. However water treatment could be applied (at a cost) to enable a poorer quality water to be converted into a better quality water in order to improve specific water use.
Type of tailings disposal facility being used	Mines that have a hydrometallurgical beneficiation plant will produce fine tailings that need to be disposed of or stored in a tailings storage facility (TSF). These facilities have a major impact on the specific water use that can be achieved, primarily due to the following factors: • The need for hydraulic transportation of the tailings requires significant volumes of water; • Water losses through evaporation from the pool on top of the TSF and from the return water dam can be significant, depending on how the pool is managed; • The TSFs are typically unlined with resultant water losses through seepage into underlying aquifers; • Water quality deterioration during the time that water is in contact with the tailings may limit the ability to reuse the water without treatment. While there are alternative options available to reduce water losses in the tailings circuit, they are not always easy to apply within the constraints of existing infrastructure and design of TSFs. However, improvements in the tailings management/disposal can lead to significant improvement in the specific water use of the mine.
Type of mining method	In many instances, the primary type of mining employed is dictated by the nature of the ore body being mined, especially with regard to deep hard rock ore bodies where underground mining is the only practical option. However, even in such mines, mining options are exercised by the mine as to whether they employ traditional stopping methods or mechanised mining. In other instances with shallower ore bodies such as encountered in the coal mining industry, alternative options are available in selecting between underground and opencast mining. In underground mining, further choices can be made with regard to mining method, e.g. bord & pillar versus high extraction. All these options have significant impacts on the mine water balance and the specific water use of the mine.

Variable Description	Comment
Size of mining operation	The size of mining operation has both positive and negative effects on WC/WDM alternatives. In some instances, large mines offer economy of scale and allow the more cost effective centralised management of water treatment to facilitate recycling and re-use. In other cases, it is found that large mining operations are dispersed over large areas, making it logistically difficult and expensive to optimally reclaim and recycle water as part of a WC/WDM strategy.
Technology in use at the mine	The technology in use at the mine is strongly correlated with the age of the mine, since many of the older mines were designed and constructed at a time when water and energy efficiency considerations were not deemed critical. While many mines in this category have and can make technology changes due to water and energy efficiency drivers, such options are often difficult and costly to implement. Newer mines, on the other hand, have been compelled to give consideration to environmental and energy efficiency aspects and are more likely to have incorporated cleaner technology into their operations. Such newer mines will have an easier task in meeting more stringent water use targets than their older counterparts.
Remaining life of mine	Mines which are near to the end of their operational life4 will be less likely to be able to justify making significant and expensive process technology and infrastructure changes in order to achieve water use targets as capital redemption can then only be applied over a short remaining life of mine. Conversely, mines with longer operational lives can justify more significant capital expenditure with longer times to redeem capital expenditure and benefit from the savings inherent in WC/WDM

Table B3: Class 3 Variables - Reasonable effort to complement WC/WDM

Variable Description	Comment
Availability / accuracy of water (and salt) balances on mine	Effective and optimised WC/WDM is not possible on mines that do not have accurate and dynamic water (and salt) balances that comply with the Best Practice Guidelines and which are supported by and regularly updated with data from effective monitoring systems. Such water balances will typically be computerised and capable of being updated to reflect water reticulation changes and data inputs. It is also important that the water balance forms the foundation of the mine's water management system and that it be actively used in developing and reviewing water management actions at all levels.
Internal water quality standards	The development of suitable water quality standards for internal water users on the mine is a critical prerequisite for the development and implementation of WC/WDM measures. Absence of such standards may result in users demanding and being supplied with a water quality that is better than what is required. As effective WC/WDM essentially entails supplying each user with the appropriate quality water that does not result in reticulation system problems (scaling / corrosion / erosion) or process efficiency problems, knowledge of what these water quality limits are, is essential.
Mine and corporate reporting requirements	Mines that adhere to rigorous corporate reporting requirements (perhaps in line with the GRI) are more likely to be sensitised to their water usage and are more likely to be engaged in a continuous improvement process aimed at systematically reducing water consumption. Conversely, a lack of structured reporting, based on outputs from an unreliable/untested water balance, is most probably indicative of a mine where WC/WDM does not enjoy any priority attention.

Table B4: Class 4 Variables – Drivers to support WC/WDM

Variable Description	Comment
Availability of fresh water resources	In areas of the country where fresh water supplies are limited and water use licences have restrictive conditions and mines are forced to develop optimised WC/WDM strategies, mine-specific water use targets may be quite stringent. While it is tempting to differentiate mine-specific water use targets based on the availability of fresh water supplies, this assumption is not logically consistent. An identical mine in a water-rich region should be equally capable of meeting the same WC targets as the mine in the water-scarce region. In fact, allowing the availability of fresh water resources (over which mines have no direct control) to be a differentiating variable in setting mine-specific WC targets, could be interpreted as offering unfair commercial advantage to mines that happen to be located in areas where fresh water is abundant. The invalidity of this variable is further highlighted by the fact that South Africa is a country with many inter-catchment water transfer schemes which artificially change the fresh water availability status of both the donating and receiving catchments.
Sensitivity of receiving catchment	The arguments against using sensitivity of receiving catchment as a variable that defines mine-specific WC targets are based on similar principles to those that were put forward for availability of fresh water resources. While the concept of differentiating catchments in terms of receiving water quality objectives as a basis of the water regulatory approach is appropriate, this should not be used to set differentiated mine-specific water use targets.
Financial status of mine	The financial status and strength of the mine and whether or not the mine is an established or emergent mine should not have any influence on the mine-specific water use targets that are set. Financially weak or young mines should not be able to use these features as a basis for setting less stringent water use efficiency targets, since the impact of such mines on the water resource and other stakeholders is the same regardless of these variables. The ability to achieve water use efficiency benchmarks should, in the interest of protecting the national water resource, rather be viewed as a minimum entry requirement into the mining sector.

APPENDIX C
WATER BALANCE MODEL

C1 Introduction

A generic mine water balance was developed in Excel, using water balance methodology developed by Golder for a wide range of different mines. The model was also constructed so that it could be run in a probabilistic (Monte Carlo) simulation mode. The primary objectives of the water balance model were to determine the following:

- Determine the effect of variables listed in the variables matrix on the key indicators
- Determine the variation in the key indicators due to differences between mines for a specific commodity as an input to the benchmark setting approach
- Quantify the savings that can be expected by implementing generic water conservation measures

The generic mine water balance included the following sections (see Figure C1 for a graphical representation of the total mine):

- Mining (opencast and underground) – Figure C2
- Beneficiation – Figure C3
- Residue disposal – Figure C4
- Other activities

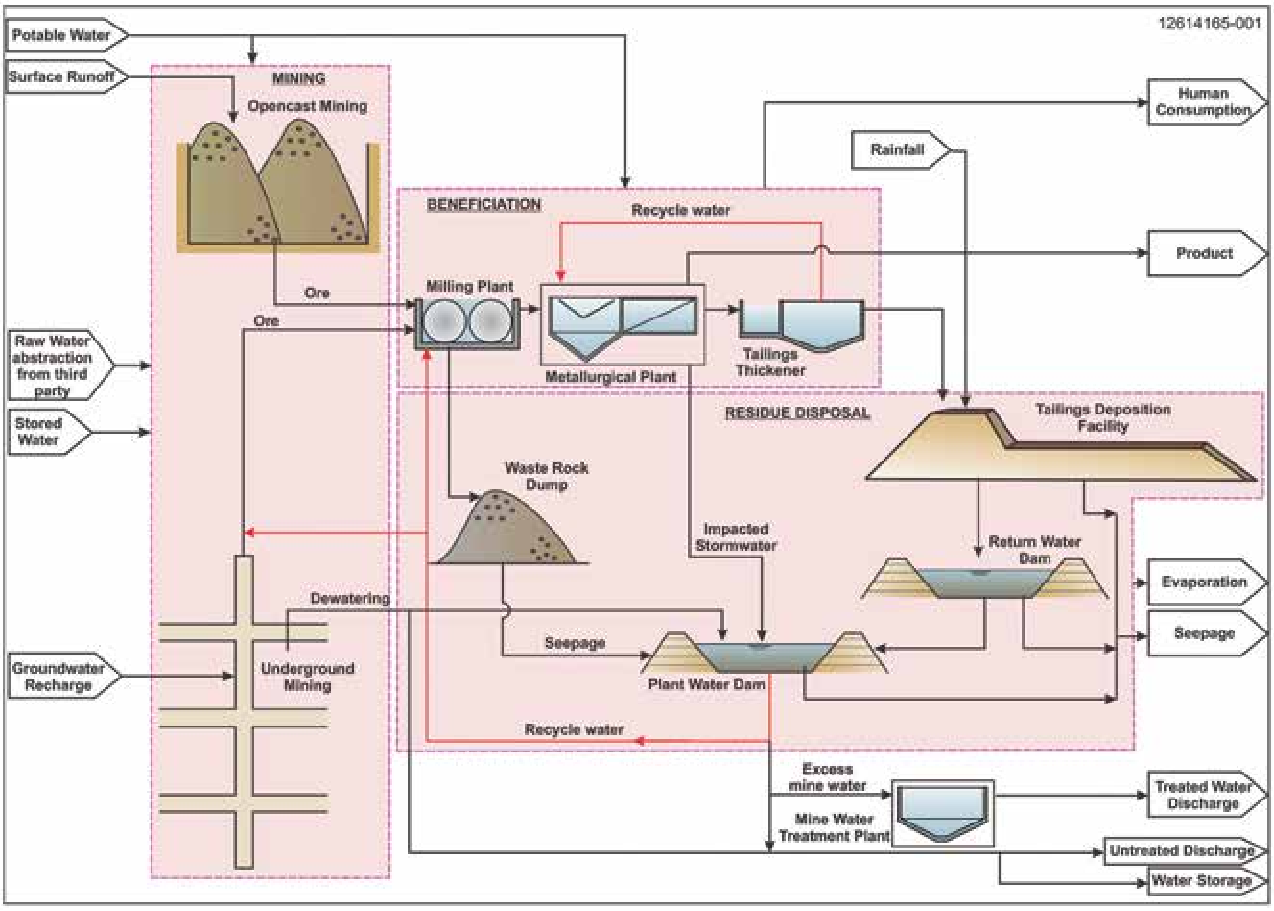


Figure C1: Total mine water balance diagram

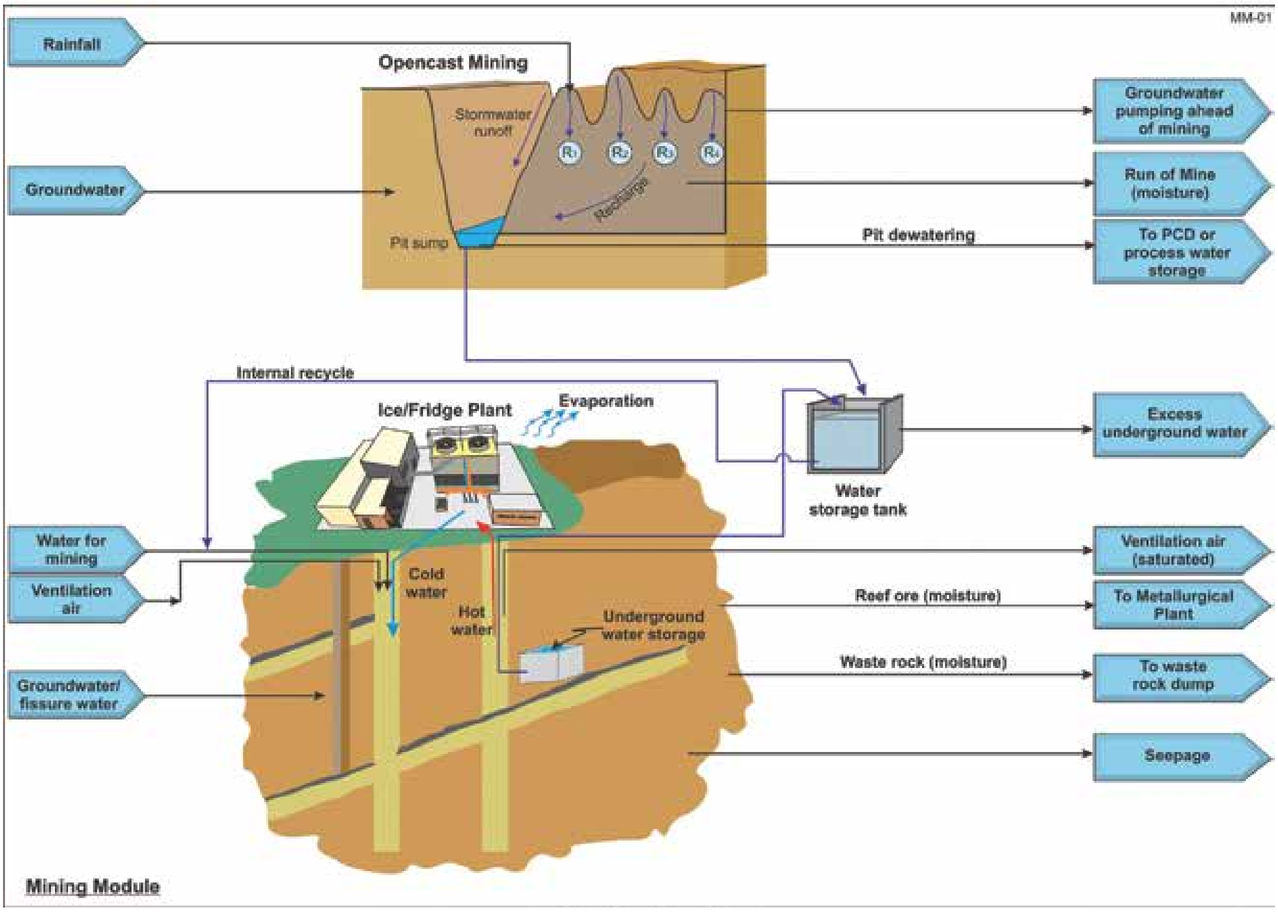


Figure C2: Mining section water balance diagram

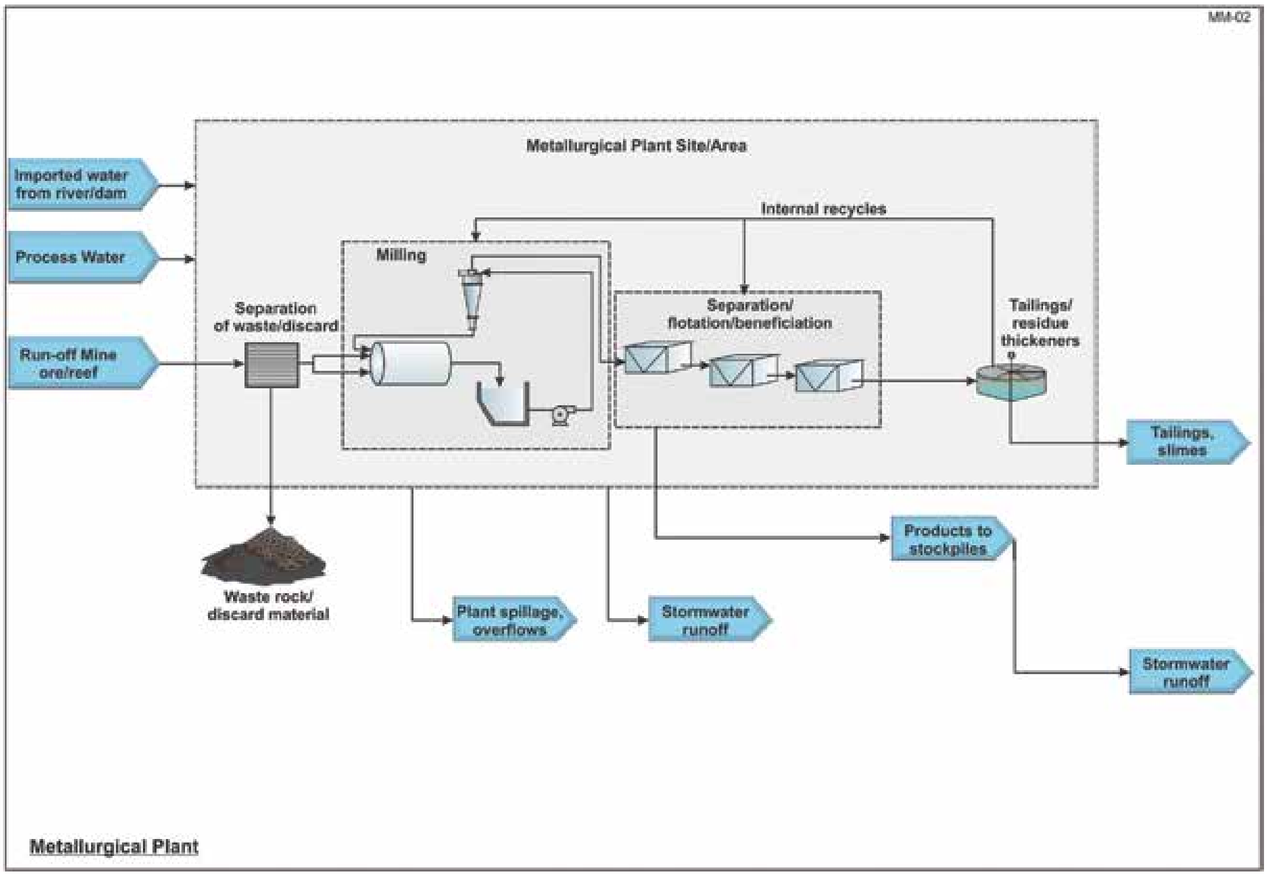


Figure C3: Beneficiation section water balance diagram

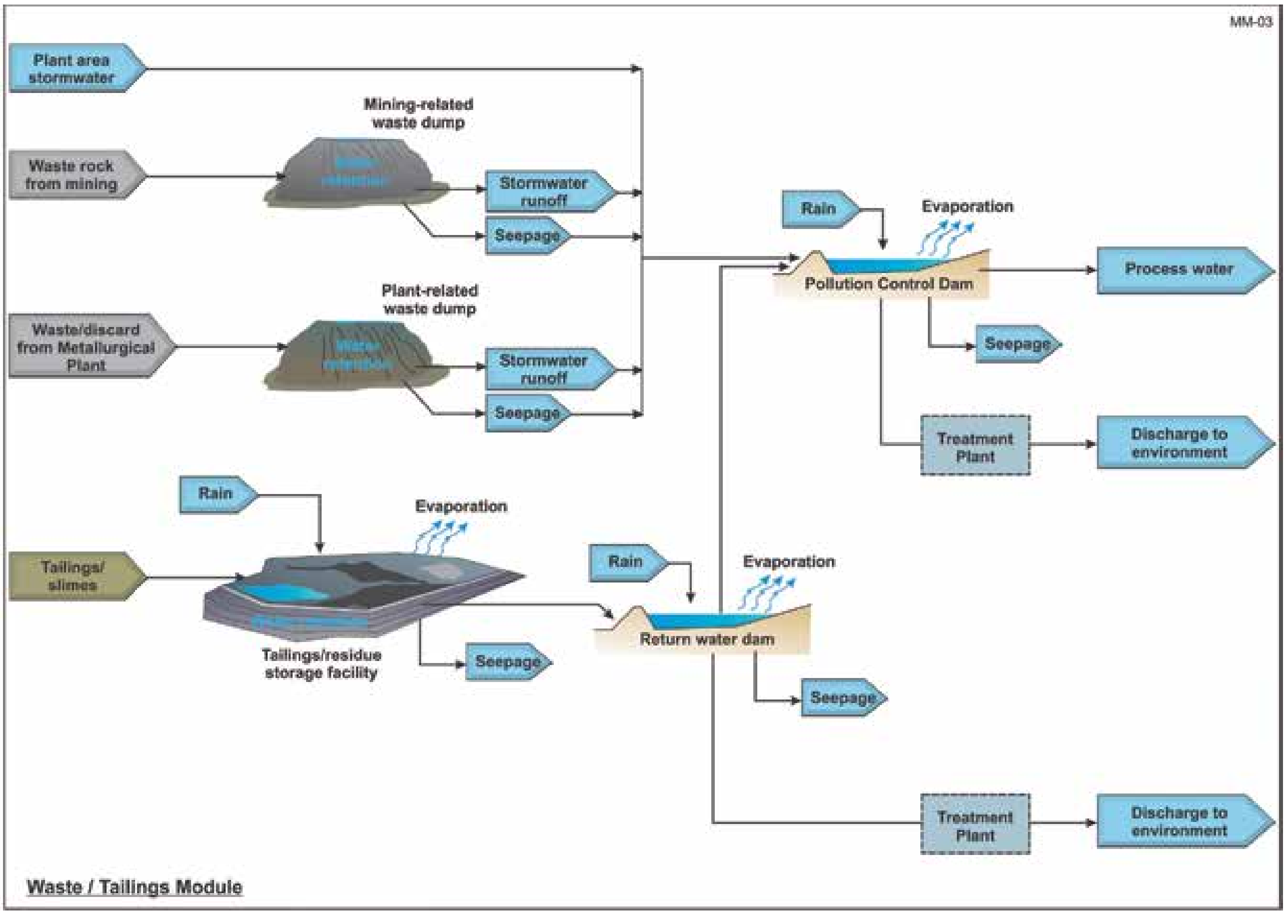


Figure C4: Residue disposal section water balance diagram

C2 Description of Water Balance Calculations

The mine water balance calculations used to calculate each inflow and outflow of the four sections are described in Table C1 to Table C4. The variables that will influence the results of the water flow calculations for each variable are also listed in these tables. These variables are linked to the variables matrix shown in Appendix B.

Table C1: Mining water balance calculations

Inflow/outflow (m^3/ year)	Type	Description of calculations	Influenced by these variables
Opencast operations			
Recharge due to rainfall on active opencast area	Inflow	Based on the average annual rainfall, % recharge of opencast pit and active opencast pit area. Opencast area is based on mining rate (t/year), seam height and duration before opencast area is rehabilitated again.	Mining rate (t/year) Climate (rainfall) % recharge (depends on opencast pit, access ramps, roads, etc.) Seam height Rehab lag

Inflow/outflow (m^3/year)	Type	Description of calculations	Influenced by these variables
Recharge due to rainfall on upstream rehab area	Inflow	Based on % recharge of rehab and upstream rehab area. Upstream rehab area is based on the area disturbed per year, the age of the mine and a factor (between 0 and 1) to cater for portion of rehab area that is downstream of active pit.	Mining rate (t/year) Age of mine Climate (rainfall) % recharge (depend on quality of rehab) Area disturbed per year (depend on seam height on tons mined) Mine plan (mining uphill or downhill)
Groundwater/fissure water	Inflow	This value is mine-specific and specified as a volume per ton mined.	Site-specific (geology, groundwater) Size of mine
Moisture in ore	Inflow	Moisture present in the ore that is mined. Calculated from a specified moisture percentage and the mining rate.	Ore moisture content (site-specific) Mining rate (t/year)
Moisture in ore	Outflow	Moisture out of the mining section due to ore mined. Calculated from a specified moisture percentage and the mining rate. Not considered a consumptive use since the water is sent to another user (beneficiation).	Same as above
Seepage, evaporation	Consumptive	Based on a percentage of the water used in the mining process.	Climate (evaporation) Site-specific (depend on geology, mining method)
Underground operations			
Recharge due to rainfall	Inflow	Based on the average annual rainfall, % recharge to underground operation and active underground area (seen from top). Underground area is based on mining rate (t/year), seam height, reef angle and duration before opencast area is rehabilitated again.	Mining rate (t/year) Climate (rainfall) % recharge (depends on underground operation, geology, etc.) Seam characteristics
Groundwater/fissure water	Inflow	This value is mine-specific and specified as a volume per ton mined.	Site-specific (geology, groundwater) Size of mine
Moisture in ore	Outflow	Moisture out of the mining section due to ore mined. Calculated from a specified moisture percentage and the mining rate. Not considered a consumptive use since the water is sent to another user (beneficiation).	Ore moisture content (site-specific) Mining rate (t/year)
Moisture out with ventilation	Consumptive	This value is mine-specific and specified as a volume per ton mined.	Site-specific (mining method, thermal gradient) Size of mine

Inflow/outflow (m^3/year)	Type	Description of calculations	Influenced by these variables
Mine cooling water loss	Consumptive	This value is mine-specific and specified as a volume per ton mined. Volume per ton mined is a function of mine depth, since deeper mines require more cooling.	Site-specific (mining method, thermal gradient, depth of mine) Size of mine
Water used for UG mining	Internal	This is an internal recycle flow that is mine-specific and specified as a volume per ton mined.	Site-specific (mining method) Size of mine
Balance			
Recycled / Raw water / water from 3rd party	Inflow	If the total inflows are less than the total outflows (outflows + consumptive), then the difference is assumed to come from recycled water from the central surface water dam (part of residue disposal) if excess water is available. If not enough excess water is available, the balance is assumed to be raw water or water from a 3de party.	From balance
Excess water to surface dams	Outflow	If the total inflows are more than the total outflows (outflows + consumptive), then the difference is to be sent to the central surface water dam (part of residue disposal). This is thus not seen as a consumptive use for mining, since it is sent to another user. All surplus water is reported in the residue disposal section.	From balance

Table C2: Beneficiation water balance calculations

Inflow/outflow (m^3/year)	Type	Description of calculations	Influenced by these variables
Moisture in ore	Inflow	Moisture in ore to beneficiation (sum of opencast and underground ore moisture). Calculated in mining section. Waste rock excluded.	Refer to mining section % ore to beneficiation
Rainfall	Inflow	Considered to be negligible.	Climate (rainfall) Beneficiation plant design and footprint
Water in tailings	Outflow	Based on SG of tailings and the dry ore and the amount of solids to tailings.	Tailings SG (depends on beneficiation method and thickening process used for tailings) SG of dry ore Solids to tailings (depends on mining rate, amount of waste rock and amount of solids to product)

Inflow/outflow (m^3/year)	Type	Description of calculations	Influenced by these variables
Water in product	Consumptive	Based on SG of product and the dry ore and amount of solids to product.	Tailings SG (depends on beneficiation method and thickening process used for product) Solids to tailings (depends on mining rate, amount of waste rock and amount of solids to product)
Impacted storm water	Outflow	Considered to be negligible.	Climate (rainfall) Beneficiation plant design and footprint
Tailings water recycle to process	Internal	This is an internal recycle flow that is calculated from the SG of the feed to the tailings thickener, the SG of the tailing and the SG of the dry ore.	SG of ore SG of thickener feed and outflow (depends on beneficiation plant design)
Balance			
Recycled / Raw water / water from 3rd party	Inflow	If the total inflows are less than the total outflows (outflows + consumptive), then the difference is assumed to come from recycled water from the central surface water dam (part of residue disposal) if excess water is available. If not enough excess water is available, the balance is assumed to be raw water or water from a 3rd party.	From balance
Excess water to surface dams	Outflow	If the total inflows are more than the total outflows (outflows + consumptive), then the difference is to be sent to the central surface water dam (part of residue disposal). This is thus not seen as a consumptive use for mining, since it is sent to another user. All surplus water is reported in the residue disposal section.	From balance

Table C3: Residue disposal water balance calculations

Inflow/outflow (m^3/year)	Type	Description of calculations	Influenced by these variables
Tailings Dams			
Water in tailings	Inflow	Based on SG of tailings and amount of solids to tailings, calculated in beneficiation section).	Refer to beneficiation

Inflow/outflow (m^3/year)	Type	Description of calculations	Influenced by these variables
Rainfall	Inflow	Calculated from the average annual rainfall and the area of tailings dam. Tailings dam area is calculated from the volume of deposited sludge remaining on the tailings dam and the annual tailings rise rate. The volume of deposited sludge is calculated from the % moisture remaining in the deposited sludge and the SG of the ore.	Climate (rainfall) Tailings dam area (calculated from tailings rise rate and volume of deposited sludge) Volume of deposited sludge (function of % solids in deposited sludge and the SG of ore)
Seepage	Consumptive	Based on pool area and the seepage rate. The pool area is calculated as a percentage of the total tailings dam area.	Seepage rate (depends on geology) Pool area (depends on how tailings dam is operated and volume of tailings produced)
Water remaining in tailings	Consumptive	Based on % moisture content of deposited sludge remaining on tailings dam.	% solids of deposited sludge
Evaporation from pool	Consumptive	Based on the average annual evaporation and the pool area.	Climate (evaporation) Pool area (depends on how tailings dam is operated and volume of tailings produced)
Evaporation from wet beach	Consumptive	Based on the average annual evaporation and the wet beach area and the wet beach evaporation factor. The wet beach area is calculated as a fraction of the total beach area, which in turn is equal to the total tailings dam area minus the pool area.	Climate (evaporation) Wet beach (depends on how tailings dam is operated and volume of tailings produced)
Evaporation from dry beach	Consumptive	Based on the average annual evaporation and the dry beach area and the dry beach evaporation factor. The dry beach area is equal to the total tailings dam area minus the pool area minus the wet beach area.	Climate (evaporation) Dry beach (depends on how tailings dam is operated and volume of tailings produced)
Tailings return water	Outflow	The difference between the total inflow and the total outflows (outflows + consumptive) for the tailings dam is equal to the tailings return water that is sent to the central surface water dam.	From balance
Rock Dumps			
Water in ore to waste rock dump	Inflow	Based on moisture content of the ore and the amount of waste rock produced (calculated as a percentage of the total tons mined).	Ore moisture content (site-specific) Mining rate (t/year) % of waste rock mined (site-specific)

Inflow/outflow (m^3/year)	Type	Description of calculations	Influenced by these variables
Rainfall	Inflow	Calculated from the average annual rainfall and the area of rock dump. The rock dump area is calculated from the waste rock produced and the rock dump rise rate.	Waste rock mined (site-specific) Rock dump area
Run-off and seepage to surface dams	Outflow	Based on a percentage of the rainfall that is captured in the pollution control dam through run-off and seepage. Not a consumptive use since the water is sent to another user (surface dam).	% runoff and seepage (depends on waste rock dump design) Rock dump area
Evaporation, seepage and interstitial storage	Consumptive	The difference between the total inflow and the total outflows (outflows + consumptive) for the rock dump is equal to the evaporation, seepage and interstitial storage.	From balance
Surface dams			
Direct rainfall	Inflow	Calculated from the average annual rainfall and the area of the surface dams. The area of the surface dams are calculated as a function of the mining rate.	Climate (rainfall) Area of surface dams (function on mine size and how the surface dams are managed)
Surface runoff	Inflow	Calculated from the average annual rainfall, the catchment area and the % runoff factor. The catchment area is calculated as a multiple of the area of the surface dams.	Catchment area (function of mine size and whether the clean storm water runoff is diverted)
Tailings return water	Inflow	Return water from tailings dam (calculated under tailings dam)	Refer to tailings dam
Rock dump run-off and seepage	Inflow	Run-off and seepage from rock dump (calculated under rock dump)	Refer to rock dump
Surplus water from mining	Inflow	Surplus water (if any) from mining. Calculated from balance of mining.	Refer to mining
Surplus water from beneficiation	Inflow	Surplus water (if any) from beneficiation. Calculated from balance of beneficiation.	Refer to beneficiation
Surplus water from other activities	Inflow	Surplus water (if any) from other activities. Calculated from balance of other activities.	Refer to other activities
Water to third party	Outflow	Specified water to 3rd party (not consumptive use since it is used by another user).	Specified

Inflow/outflow (m^3/year)	Type	Description of calculations	Influenced by these variables
All water discharged or disposed of	Outflow	All or any water discharged or disposed of and not recycled contributes to water lost from the mining operations and % of water not reused.	Specified
Evaporation	Consumptive	Calculated from the average annual evaporation and the area of the surface dams. The area of the surface dams are calculated as a function of the mining rate.	Climate (evaporation) Area of surface dams (function on mine size and how the surface dams are managed)
Seepage	Consumptive	Calculated from the seepage rate and the area of the surface dams. The area of the surface dams are calculated as a function of the mining rate.	Seepage rate (depends on geology) Area of surface dams (function on mine size and how the surface dams are managed)
Water to mining	Outflow	Available surplus water sent to mining if mining requires make-up water (calculated under mining)	Refer to mining
Water to beneficiation	Outflow	Available surplus water sent to beneficiation if beneficiation requires make-up water (calculated under beneficiation)	Refer to beneficiation
Water to other activities	Outflow	Available surplus water sent to other activities if other activities requires make-up water (calculated under other activities)	Refer to other activities
Balance			
Raw water / water from 3rd party	Inflow	If the total inflows is less total outflows (outflows + consumptive), then the difference is assumed to come from raw water or water from a 3rd party.	From balance
Water or wastewater discharged	Outflow/Consumptive	If the total inflows are more than the total outflows (outflows + consumptive), then the difference must be discharge. The discharged water is calculated as a percentage of this total discharge (this percentage should be 100%). This is seen as a consumptive use since the discharge water should be recycled (it might require treatment).	From balance and % of discharge that is clean water
Untreated spillages/ discharges	Consumptive use	The untreated spillages/ discharges are calculated as the difference between the total discharge and the clean discharge (this should be zero). This is seen as a consumptive use since it should be reused with or without treatment.	From balance and % of discharge that is dirty

Table C4: Other activities water balance calculations

Inflow/outflow (m^3/year)	Type	Description of calculations	Influenced by these variables
Haul road dust suppression	Consumptive	Based on the dust suppression application rate (mm/d) and the total haul roads area. The haul roads area is calculated from the haul roads length and width. The haul roads length is a function of the size of the mine and the nature of the mining operation.	Dust suppression application rate (depends on climate, whether binding medium is used on roads) Length of haul roads (depends on size of mine and nature of operation) Width of haul roads
Service road dust suppression	Consumptive	Based on the dust suppression application rate (mm/d) and the total haul roads area. The service roads area is calculated from the service roads length and width. The service roads length is a function of the size of the mine and the nature of the mining operation.	Dust suppression application rate (depends on climate, whether binding medium is used, tarred, etc.) Length of service roads (depends on size of mine and nature of operation) Width of service roads
Human consumption (potable water)	Inflow	Water used by workers (potable and for showers). Number of workers depends on mining method and nature of operation. Calculation is based on an average water usage per worker per day with shower access and an average water usage per worker per day without shower access.	Number of workers with and without shower access (depend on mining method and size of mine) Average water usage per worker (dependent on climate)
Sanitation water reused as process water	Internal	Based on a percentage of the sanitation water that is reused as process water. This will depend on treatment of sanitation water. The amount of sanitation water is equal to the human consumption minus the water lost through perspiration, breathing and evaporation	Specified Amount of sanitation water and treatment thereof
Water lost through perspiration, breathing and evaporation	Consumptive	Based on average water lost per worker per day (dependent on climate).	Number of workers (depend on mining method and size of mine)
Sanitation water discharged	Consumptive	Sanitation water not reused	Amount of sanitation water and treatment thereof
Balance			

Inflow/outflow (m^3/year)	Type	Description of calculations	Influenced by these variables
Recycled / Raw water / water from 3rd party	Inflow	If the total inflows are less than total outflows (outflows + consumptive), then the difference is assumed to come from recycled water from the central surface water dam (part of residue disposal) if excess water is available. If not enough excess water is available, the balance is assumed to be raw water or water from a third party.	From balance
Excess water to surface dams	Outflow	If the total inflows are more than the total outflows (outflows + consumptive), then the difference is to be sent to the central surface water dam (part of residue disposal). This is thus not seen as a consumptive use for mining, since it is sent to another user. All surplus water is reported in the residue disposal section.	From balance

C3: Results of Water Balance Simulations Undertaken

As mentioned previously, the model was used to undertake the following:

- Determine the effect of variables listed in the variables matrix on the key indicators
- Determine the variation in the key indicators due to differences between mines for a specific commodity as an input to the benchmark setting approach
- Quantify the savings that can be expected by implementing generic water conservation measures

The results of these analyses are reported below.

C3.1: Effect of variables in variables matrix on key indicators

The model as it was constructed was capable of evaluating the effects of the following variables listed in the variables matrix (Appendix B) on the key indicators:

- average annual rainfall
- average annual evaporation
- ground water / fissure water ingress into mining operations
- depth of mine (for underground mines)
- mine cooling requirement

The results of these simulations are shown in Figures C5 through to C9 below in terms of the effect of these parameters on the total water input per ton (specific water use) for the four major commodities. This will give an indication of how sensitive the water usage of a mine is to these parameters and how this will affect specific water use for the different mining operations and also quantify how much water can be saved by changing these parameters. In each simulation, only the variable under consideration was varied and all other variables were kept at their reference values.

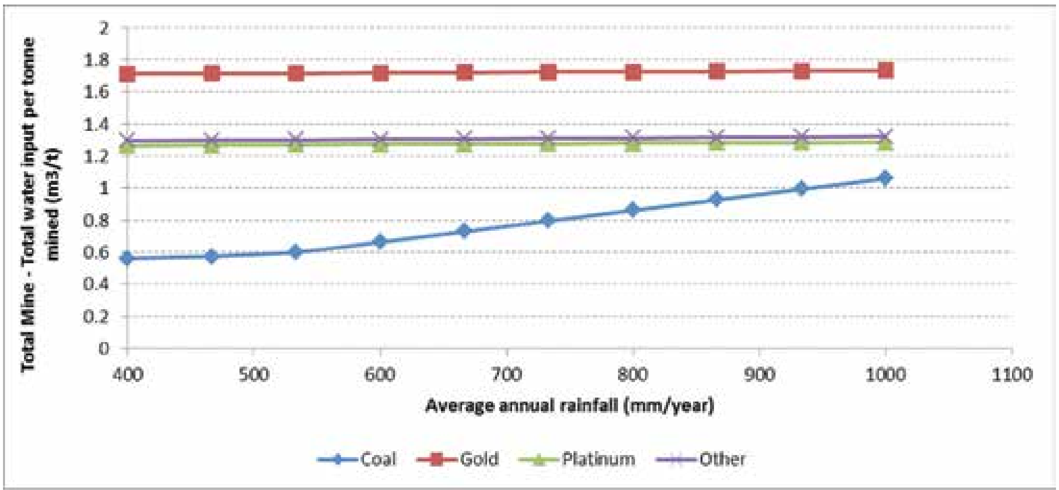


Figure C5: Effect of annual rainfall on total water use efficiency

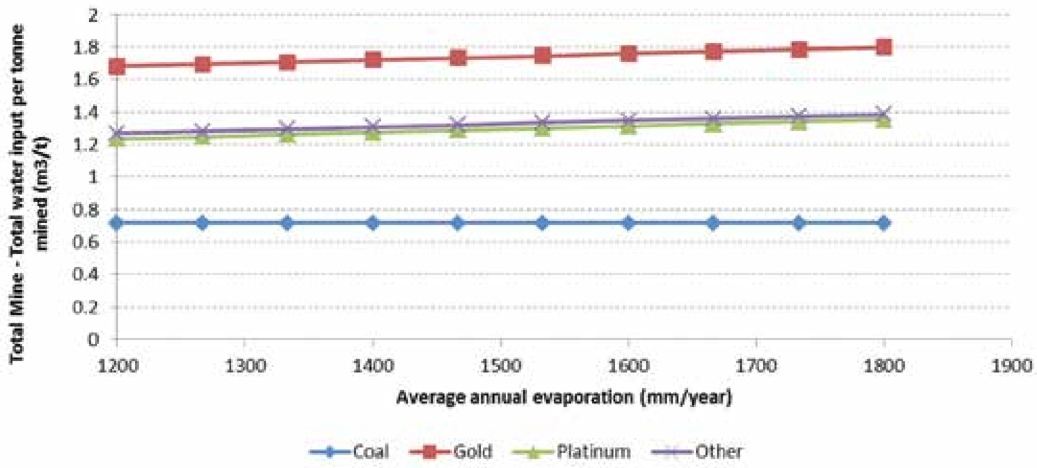


Figure C6: Effect of annual evaporation on total water use efficiency

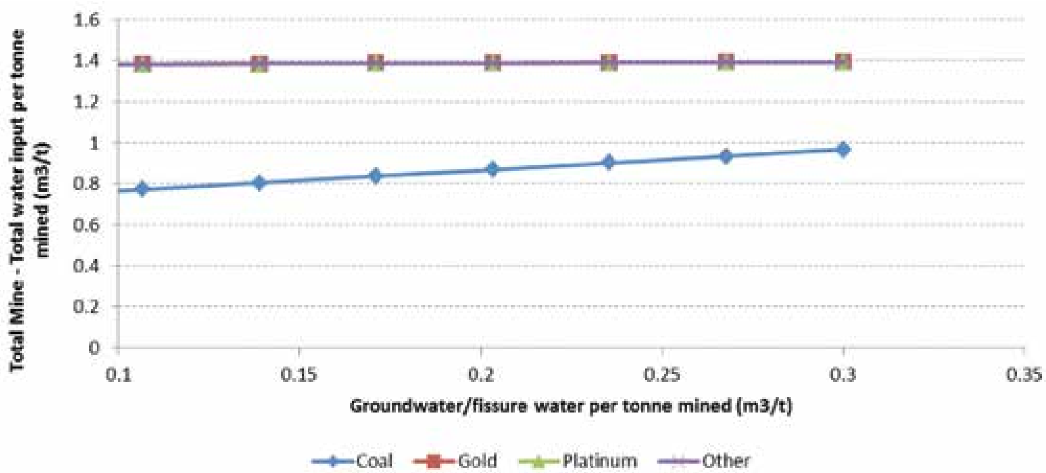


Figure C7: Effect of ground water / fissure water make on total water use efficiency

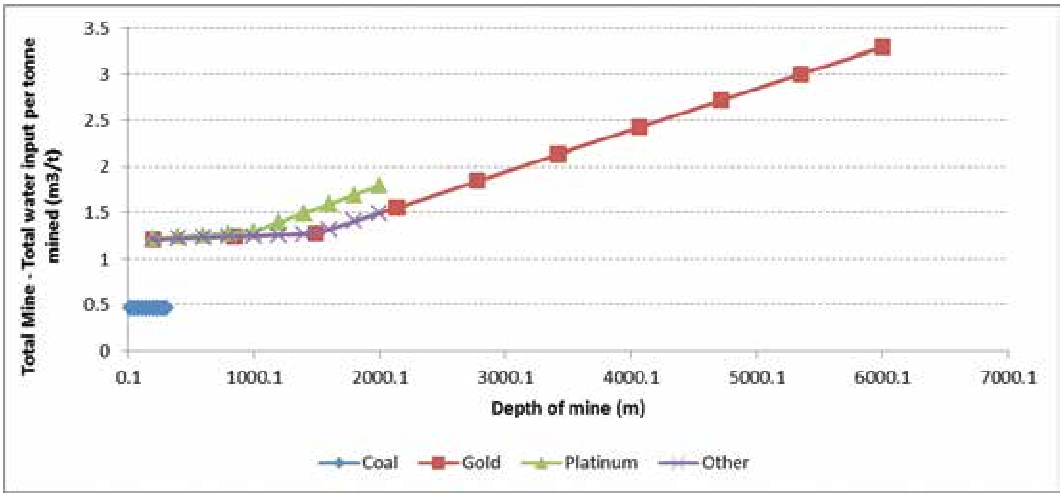


Figure C8: Effect of depth of underground mines on total water use efficiency

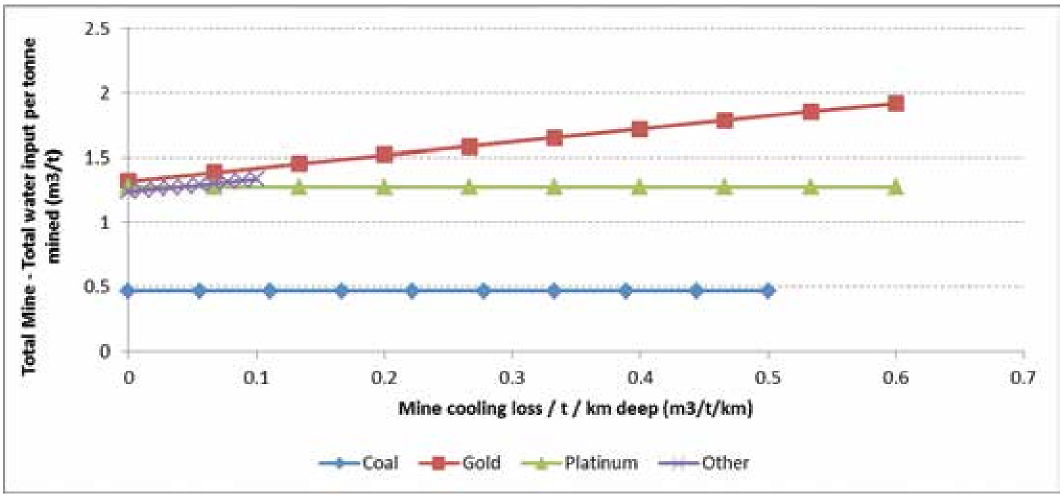


Figure C9: Effect of depth of mine cooling water requirement on total water use efficiency

The parameters shown in Figures C5 to C9 are defined as class 1 variables in the variables matrix as they are fixed features of a mine and cannot be changed. This is important insofar as these variables will directly affect the achievable water use indicators of a mine. For example, with all other variables being the same, it would be expected (as shown in Figure C8) that a deep mine would have a higher water use requirement than a shallower mine. When evaluating the data shown in Figures C5 to C9, the actual predicted variation in specific water use is of less significance than the trend, be it for improved or worsened water use efficiency.

C3.2: Effect of natural variation of water balance parameters on key indicators

The model was constructed to be capable of operating in a probabilistic (Monte Carlo) mode where all the input values were randomly sampled and the model was then run 500 times for each of the commodity groups. The outputs of the model were then plotted and statistically evaluated to determine the variation in water use indicator that could be expected, given a natural variation in these input values at different mine sites. The results of these 500 simulations are shown for the coal mining scenario (similar results were obtained for each commodity) in the Figures below and the results for all the simulations are shown in Table C5 below. Figures C10 to C14 show the results of the Monte Carlo simulations for the total mine water balance, the mining water balance, the beneficiation water balance, the residue disposal water balance and the water balance for other water uses.

Table C5: Standard deviation of key indicators per commodity

Standard Deviation	Unit	Coal	Gold	Platinum	Other
Total Mine					
Total Mine - Total specific water use per ROM ton	m^3/t	0.19	0.49	0.22	0.20
Total Mine - Consumptive specific water use per ROM ton	m^3/t	0.17	0.50	0.22	0.20
Total Mine - % waste water not recycled	%	12%	13%	13%	13%
Total Mine - Water recycle ratio	%	32%	32%	37%	35%
Mining					
Mining - Total specific water use per ROM ton	m^3/t	0.22	0.40	0.11	0.11
Mining - Consumptive specific water use per ROM ton	m^3/t	0.02	0.47	0.10	0.05
Beneficiation					
Beneficiation - Total specific water use per ROM ton	m^3/t	0.23	0.28	0.27	0.27
Beneficiation - Consumptive specific water use per ROM ton	m^3/t	0.00	0.00	0.00	0.00
Residue Disposal					
Residue Disposal - Total specific water use per ROM ton	m^3/t	0.35	0.37	0.33	0.34
Residue Disposal - Consumptive specific water use per ROM ton	m^3/t	0.15	0.19	0.19	0.19
Other Activities					
Other Activities - Total specific water use per ROM ton	m^3/t	0.08	0.05	0.06	0.08
Other Activities - Consumptive specific water use per ROM ton	m^3/t	0.08	0.05	0.06	0.08

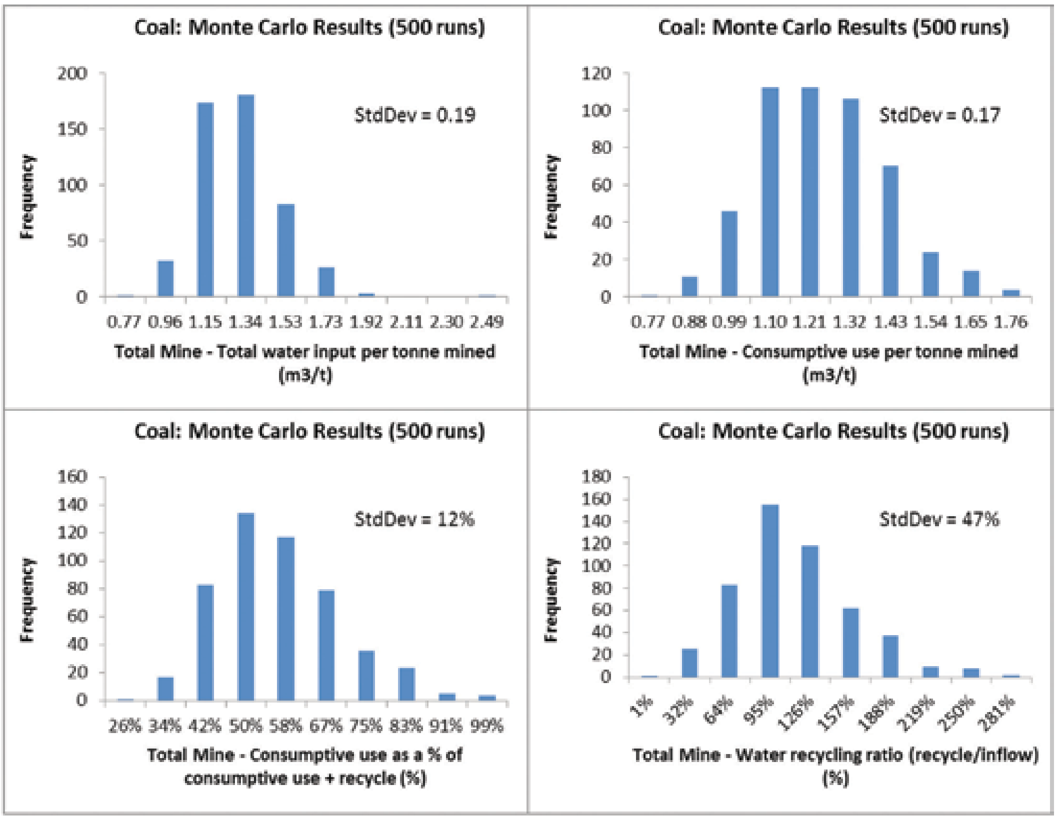


Figure C10: Effect of variations on total mine water balance key indicators

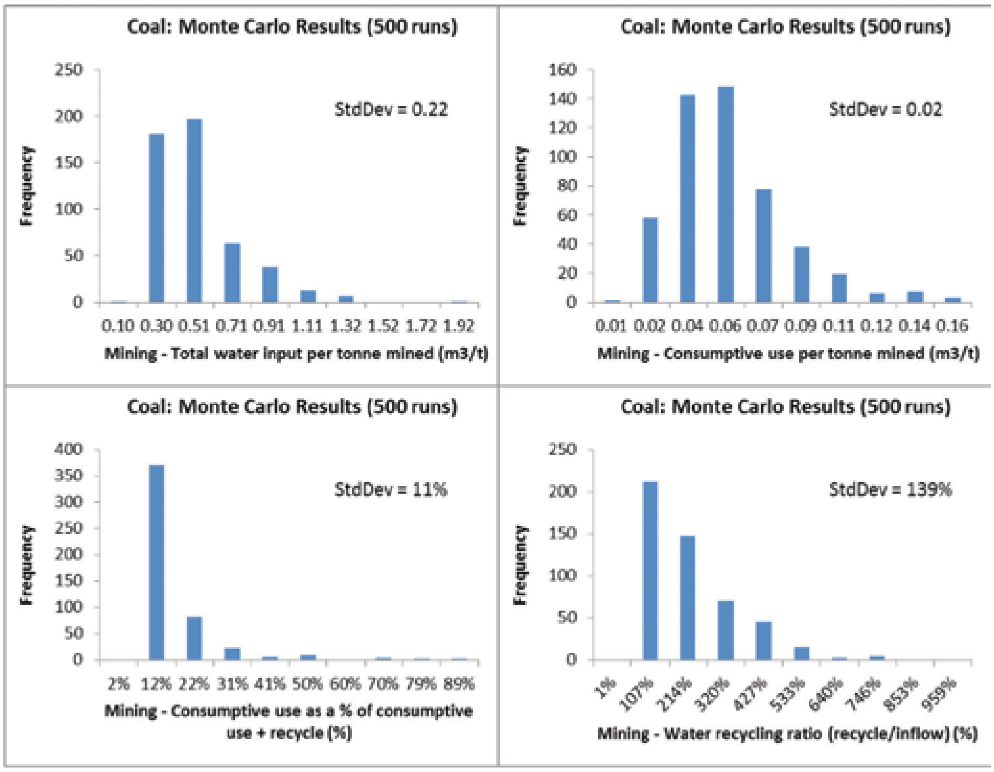


Figure C11: Effect of variations on mining water balance key indicators

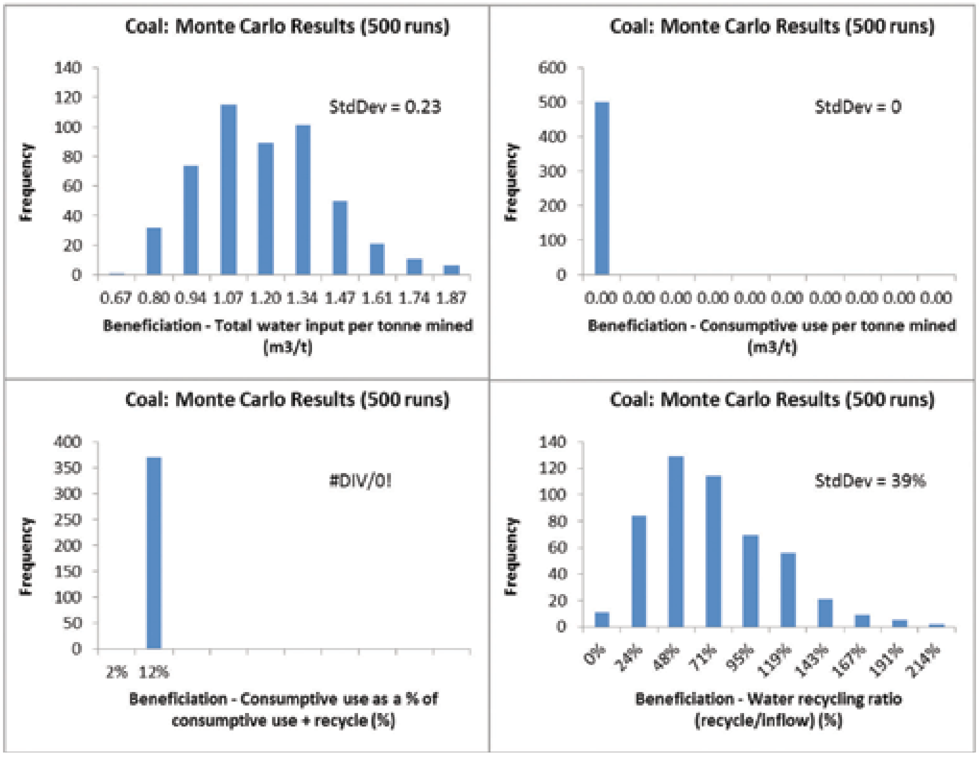


Figure C12: Effect of variations on beneficiation water balance key indicators

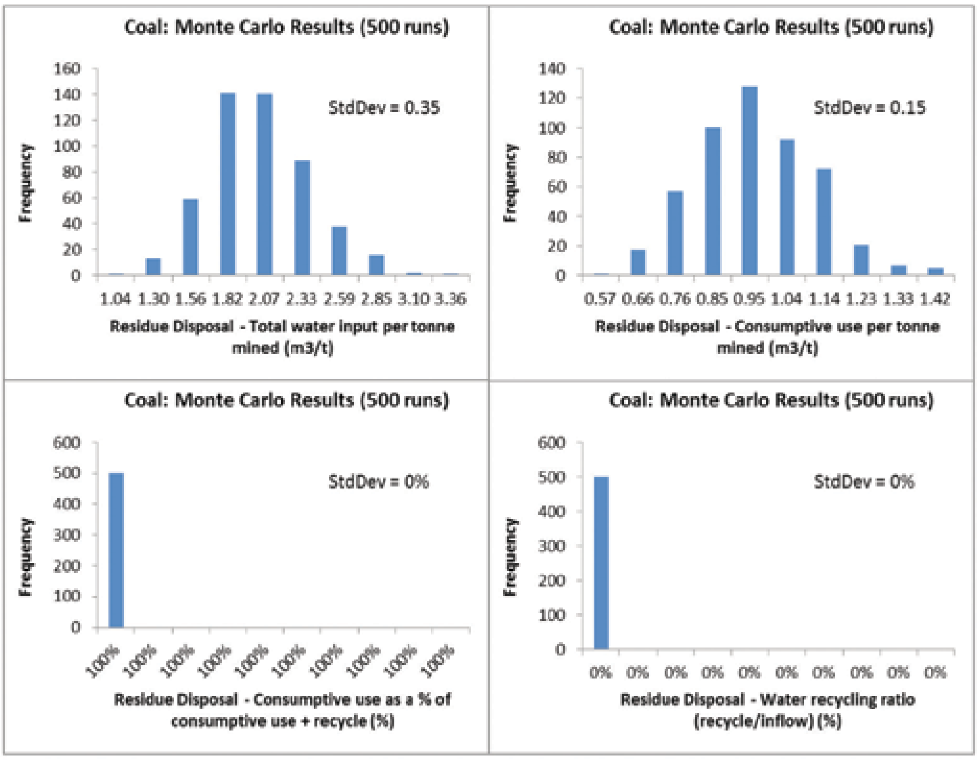


Figure C13: Effect of variations on residue disposal water balance key indicators

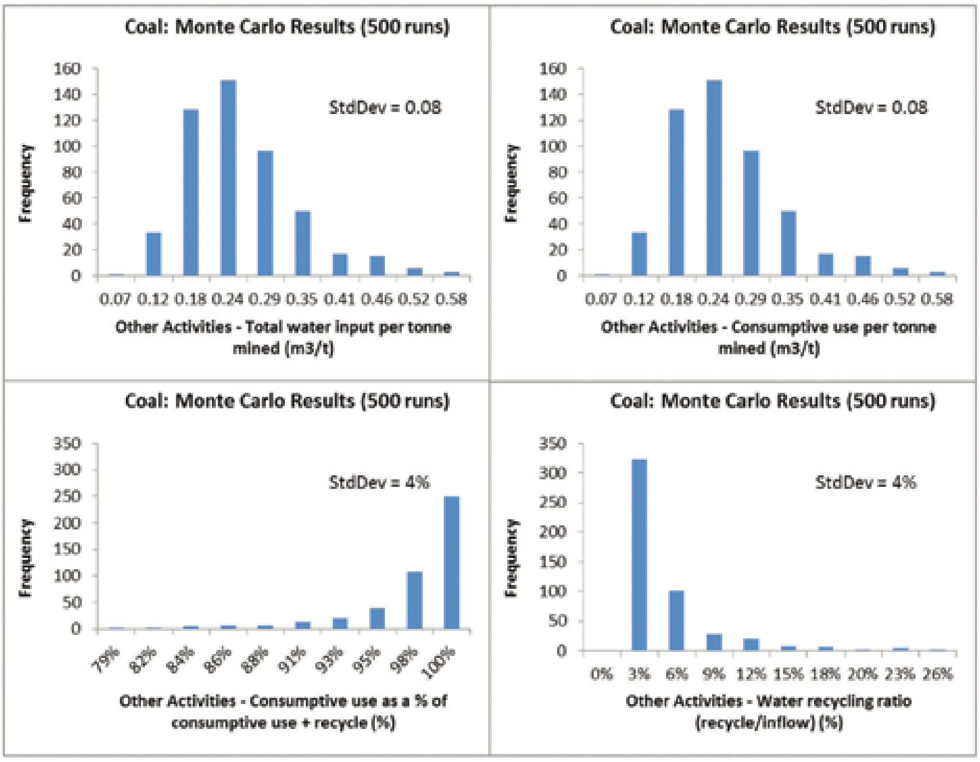


Figure C14: Effect of variations on other use water balance key indicators

The purpose of the Monte Carlo simulations was to evaluate the natural variation around the average values for the key indicators that could be expected if a large number of mines were to be evaluated. The standard deviations determined during this exercise are then also applied to define the range that should be allocated to the average national benchmarks set for each of the key indicators.

NOTES

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