BENCHMARKS FOR WATER CONSERVATION AND WATER DEMAND MANAGEMENT (WC/WDM) IN THE MINING SECTOR

WC/WDM BENCHMARKS REPORT

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 and 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 WCWDM 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 & GLOSSARY

ABBREVIATIONS

BPG:	Best Practice Guideline (documents issued by the DWS)
DWS:	Department of Water and Sanitation
EWULAAS:	Electronic Water Use License Application and Authorisation System
NWA:	National Water Act, 1998 (Act 36 of 1998)
NWRS2:	National Water Reconciliation Strategy, Second Edition
ROM:	Run of mine
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
WUE:	Water Use Efficiency

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:	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 organisations 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:	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):	Defined and prescriptive procedure/framework whereby the mine submits its WC/WDM plan (including water balance information, targets and management actions) and 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 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 and Sanitation, 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 entailed a number of key tasks that were aimed at supporting the development of these WC/WDM targets, including the following:

1. Literature review to evaluate different approaches and methodologies followed internationally in setting water use targets.

2. Development of a variables matrix that identifies those 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 balancedata 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 anupdated 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 above is described in this report. The outcome of the fourth step is contained in a separate report entitled: **"Guideline for the Development and Implementation of Water Conservation and Water Demand Management Plans for the Mining Sector".**

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
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.

b) 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.

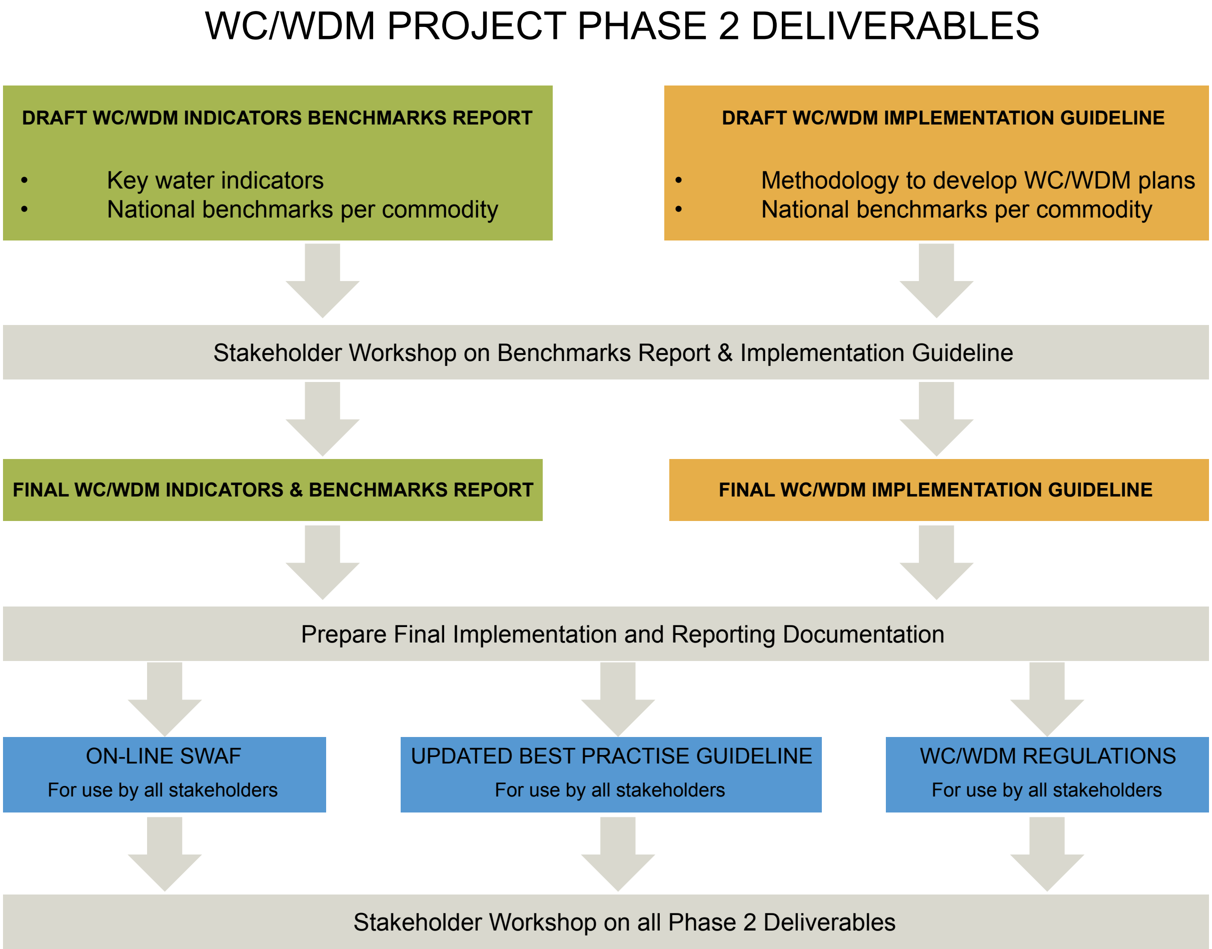

Figure 1: WC/WDM project phase 2 deliverables

2. KEY WATER USE INDICATORS

The identification of which water use indicators should be used to guide WC/WDM in the South African mining industry is based on the outcomes of the literature review and the inputs received from the mining and regulator stakeholders that have provided inputs into the project in the various Stakeholder workshops. Based on the outcome of this process it was decided that this project will focus on two categories of water usage as defined below and as illustrated in Figure 2 below.

1) **Total water use:** Total intake of all water entering the operation. This includes rainfall and runoff that is not separated from and diverted around the operation(e.g. contaminated rainwater runoff that is recycled and re-used), groundwater make and/or abstraction, water obtained from water supply boards, water abstracted from any surface water resource, wastewater (or any other water) obtained from an external third party.

2) **Consumptive water use:** As shown in Figure 2, this excludes two categories of water:

- water that is diverted around the mine's operations (e.g. groundwater abstracted from dewatering bore-holes and sent to a third party off-site user)
- water that has been through the mine's operations but which is sent to an off-site third party (e.g. farmer, other mine, industry) for beneficial use by that party

Once the exclusions are removed from the mine's water inputs, then the balance that remains is deemed to be the consumptive water use. This category of water use will normally be lower than the Total Water Use.

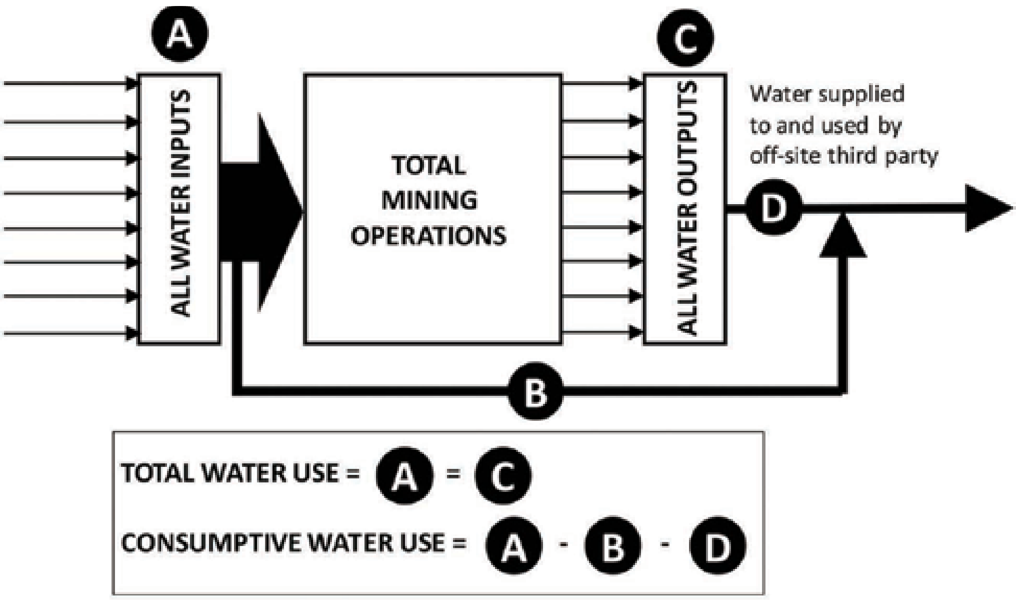

Figure 2: Distinction between total water use and consumptive water use

In terms of deciding which water use indicators should be considered for WC/WDM in the South African mining industry, particular attention was paid to the following references used in the literature review:

i) Global Reporting Initiative (GRI)

While the GRI (https://www.globalreporting.org/standards/g4/Pages/default.aspx) makes use of a number of performance indicators, the following are particularly relevant to WC/WDM and are related to the water balance shown in Figure 3 below in the following manner:

- G4-EN8: Total water withdrawal by source (equivalent to Total Water Use as shown in Figure 3, except that source of water is individually reported and is reported in m^3/annum instead of m^3/day)
- G4-EN10: Percentage and total volume of water recycled (the percentage of water recycled is equivalent to the recycle ratio as shown in Figure 3, while the total volume of water recycled is equivalent to the sum of all the "D" flows shown in Figure 3 and is reported in m^3/annum instead of m^3/day)
- G4-EN 21: Total water discharge by quality and destination (equivalent to the sum of all the water outputs for the Total Mine as shown in Figure 3, except that destination sink is reported and the quality of the water discharged is also reported and the data is reported in m^3/annum instead of m^3/day)

ii) Minerals Council of Australia – Water Accounting Framework for the Minerals Industry

Key principles that underpin the Water Accounting Framework (WAF) (see the Implementation Guideline Report for more details on the WAF) can be summarised as follows:

- 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; and
- A consistent approach in quantifying and reporting water 'reuse' and 'recycling' efficiencies such that the reliance on sourced water is reduced.

iii) Policy and Strategy for Managing Water Quality in South Africa and WC/WDM Guideline for the Mining Sector

A key consideration given in the development of South African policies and strategies for managing water quality as well as water conservation and demand management in the South African mining sector were the scarcity of water (South Africa being the 30th water scarce country in the world) as well as water quality impacts on this scarce resource. A hierarchy for managing water quality as well as water conservation and demand management has been developed in 1991 and in 2011 which requires the minimisation, re-use and recycling of all water with the discharge of water or wastewater as a last resort, thereby promulgating the optimal use of South Africa's scarce water resources. While this policy has been implemented over many decades, there is considerable scope for further implementation within the South African mining sector.

Based on consideration of the above, the key indicators shown below have been agreed to be relevant in terms of water conservation/water demand management and will be used in this project. The manner in which these indicators are determined using the generic water balance used for the site engagements is shown in Figure 3 below.

Volumetric indicators

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

Water use efficiency indicators

- 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 wastewater not recycled or reused - calculated as the volume of wastewater lost from the operations divided by the sum of the consumptive water use plus the recycled/reused water (%).
- Water recycling ratio (all recycle and reuse streams added together and reported as a percentage of total water use plus recycle/reuse volumes) (%)

The key indicators listed above can be applied to the total mine (and all operations associated with the mine), as well as to individual mining operations (e.g. mining, beneficiation and residue disposal). Note that the production measure used for the individual mining operations will differ, e.g. residue disposal might be expressed per mass of material disposed.

Data collected during the site visits does allow the setting of benchmark ranges for total specific water use and consumptive specific water use per major commodity. However, the quality and completeness of water balance data obtained during the site visit does not support the derivation of similar benchmarks, with the same degree of confidence, for the sub-process balances, i.e. mining operations; beneficiation plants and residue disposal and values presented in Appendix D of this report for these parameters are based on much smaller datasets.

The calculated values for the key indicators for all the mines included in the site engagements are shown in Appendix A.

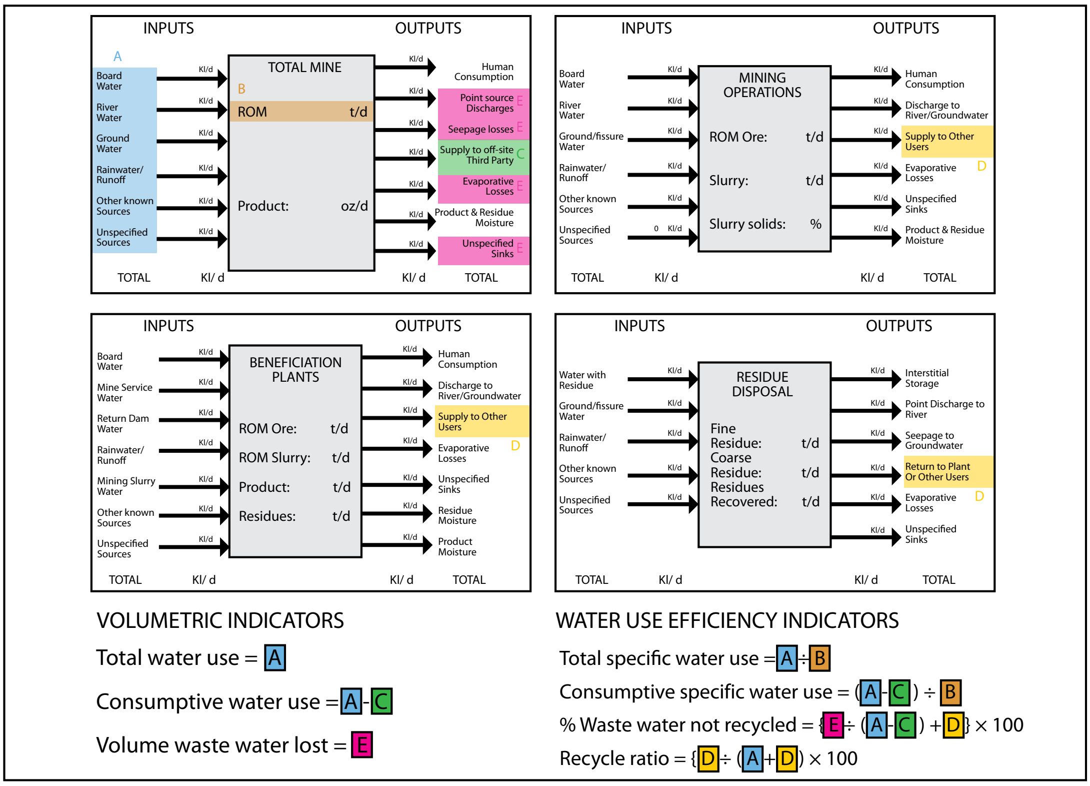

Figure 3: Generic water balances and key indicators

3. SETTING OF NATIONAL WATER USE EFFICIENCY BENCHMARKS

3.1. General Description of National Benchmark Setting Process

The commodity-based benchmarks established in this step are derived from the information gathered during the site visits to the 39 mines selected for this project. Mines should consider these benchmarks when developing their site-specific WC/WDM plan. These national benchmarks will be used by DWS in reviewing individual mine WC/WDM plans and site-specific water use efficiency targets to ensure that they are realistic and in-line with industry commodity norms. The methodology for considering the national benchmarks in relation to the individual targets developed by each mine will be described in the Guideline for the development and implementation of Water Conservation and Water Demand Management Plans for the Mining Sector.

The method that was used to derive national water use efficiency benchmarks is described below:

- The current baseline water use per commodity was determined by evaluating the water usage data at each of the 39 visited mines, as well as mine production data (tons of ore mined). This determines the average “Current Total Specific Water Use” for a particular commodity. This baseline specific water use may also be expressed in terms of individual processes such as mining, minerals beneficiation, residue handling and disposal, etc., wherever data density supports this (see Tables in Appendix D).

- Secondly, it was apparent that the water balances obtained for a number of the mines were seriously flawed. An exercise was undertaken to attempt to objectively identify those mines and then to discard these water balance data as their inclusion was skewing the information and hence conclusions that were being drawn.

- The information collected from the site visits was then objectively evaluated to identify those mines that have shown good progress with implementation of general water management measures. While these mines generally also showed the most progress with regard to the development and implementation of WC/WDM measures, it must be highlighted that in general, WC/WDM within the mining industry (including the top water management mines) is still largely focused on reducing potable water use and less on improving overall efficiency in water use regardless of the quality or source. The water use of the top three mines was subsequently evaluated in relation to the current average baseline ranges using the complete data set and this was used to define the initial national specific water use benchmarks for each mineral commodity. This exercise was undertaken for only the coal, gold, platinum commodities and all other mining commodities were grouped under "other".

- These specific water use benchmarks are defined as "national benchmarks" and a range above and below the average national benchmark was defined in order to set the national benchmark range. This range was derived from the consideration of critical variables, including where possible, those described in the variables matrix. A water balance tool that can be used to assess the effects of the key variables on the national benchmarks for the different commodities was developed and used for this exercise.

The process described above is shown graphically in Figure 4 below.

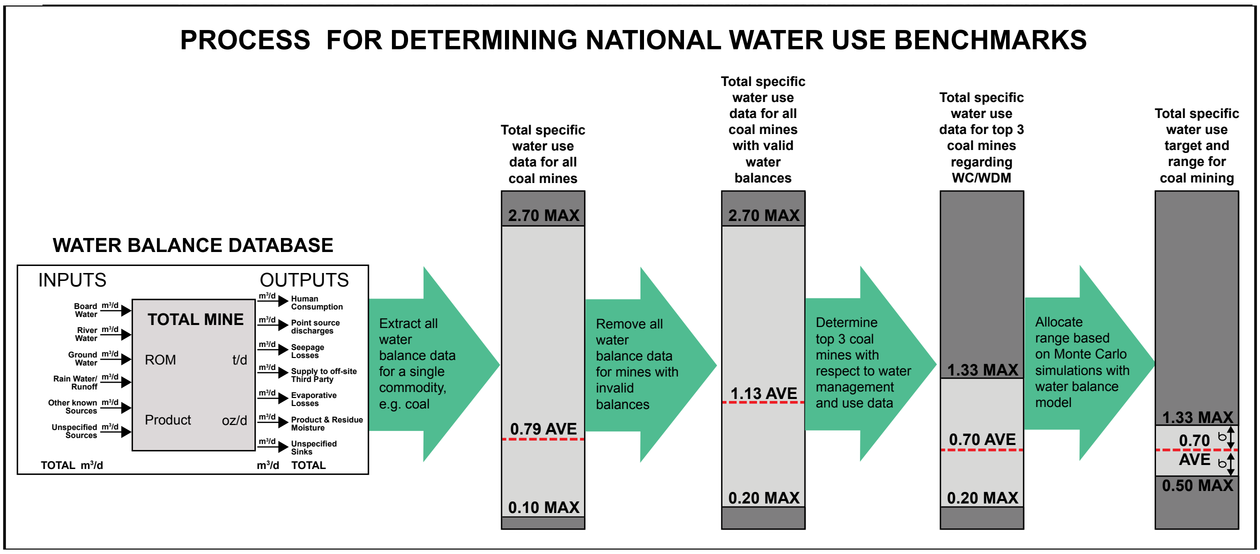

Figure 4: Process for determining the national water use efficiency benchmarks for each mining commodity

A review of available literature indicates that the approach of setting national targets has not been attempted in any other country, presumably due to the fact that there are such a large range of variables that affect water use efficiency on a mine. As the precise effect of all these variables cannot be explicitly evaluated or quantified, the international approach has been to focus on ensuring that there is a consistent and accurate methodology for measuring and reporting water use and to then use this as a platform for the implementation of methodologies to enable individual mines to set their own internal targets.

The approach described in this Chapter is based on an evaluation of the data collected during the site visits in order to identify those mines that represent relatively good water management practices and to use their performance data as a benchmark for other mines within the same commodity group. It is also acknowledged that the benchmarks derived from the better performing mines do not represent the final desirable performance end point for that commodity, as even these better performing mines themselves have much room for improvement. This implies that the benchmarks could change in future and follow a process of continuous improvement.

It must also be remembered that the better performing mines that were used to develop the benchmarks each represent very specific mining situations and that there will be mines that have a specific combination of the variables described in the variables matrix who will be unable to meet these benchmarks no matter how much effort they put into implementing WC/WDM measures.

Given the abovementioned caveats, it is deemed more appropriate to refer to the outcome of the process described in Chapter 3 as national commodity **benchmarks** rather than national **targets.**

The national benchmarks developed using the method described above therefore serve as the initial national benchmarks. As mines start developing and implementing effective WC/WDM plans, these national benchmarks are expected to become more stringent (move downwards) to reflect the increased maturity of WC/WDM in the sector and the reduced availability of South Africa's water resources.

3.2. Discussion of National Benchmark Setting Process

In order to calculate the benchmarks using the method described above, more than three mines are required per grouping (commodity) to get meaningful results. Of the mines evaluated, only coal, gold and platinum had more than three mines with usable data. Benchmarks have therefore been calculated for these three commodities, whilst all the other commodities have been grouped under "other". The commodity-based national benchmarks have therefore been developed for the following commodities:

- Coal;
- Gold;
- Platinum; and
- Other (includes diamonds, chrome, iron ore, manganese, copper, phosphate, heavy mineral sands, dolomite quarries and others)

It is clearly understood that the group "other" contains a very diverse range of mining commodities which also represent quite a diverse range of mining methods and that it is problematic to include such a diverse set of mines into a single group. However, the data density for the "other" mining commodities is simply too low to allow the process described in this section to be applied and there are only two possible options available to the project team. Firstly, group all such mines into a single "other" grouping and highlight the problem and reduced confidence in the data reported for the "other" grouping. Secondly, benchmark setting could be confined to the three major commodities with no values reported for the other commodities, other than indicating the range of values actually found from the site visit data.

The steps that were followed to calculate the water use benchmarks and the calculated results are explained in detail below. The discussion presented below generally only refers to the total specific water use indicator although the same exercise was undertaken for all the listed performance indicators except the indicator "volumes of wastewater lost through discharges, seepage and evaporation" as this indicator was only added after all the calculations had been completed.

3.2.1. Step 1: Calculate Current Baseline Total Specific Water Use

The first step in calculating the benchmarks was to determine the current baseline total specific water use per commodity. As a first step, this was calculated using all the mines that were evaluated. The results are shown in Table 1.

Table 1: Average specific total water use per ROM ton for all mines

Commodity	Total water input (m^3 per ROM ton) (average of all mines)
Coal	0.79
Gold	2.46
Platinum	1.68
Other	1.23

3.2.2. Step 2: Discard Invalid/Poor Water Balances

In order to ensure that the benchmarks are based on valid and correct water balances, the total water balance of each mine was evaluated in terms of its accuracy and completeness. This was done as follows:

- Each mine was given an initial score of five points.

- Values/points were subtracted for omissions and discrepancies in the water balance.

- All mines with a final water balance score of below 1 were discarded as their water balances were considered to be too inaccurate and that incorporation of these data would skew and misrepresent the actual total water usage on mines.

- All outlier mines with extremely high (>400% of average) or low (<25% of average) specific water use (based on total water use per ton of ore mined) were also discarded. This was done as these values are considered unrealistic and were deemed most likely to be due to incorrect water balance or production data and not representative of the industry in general.

- The average total specific water use per commodity was then recalculated based on the valid/accepted water balances.

In terms of the evaluation, the water balances of the mines were first penalised for omissions of critical inputs and outputs. On a high level, most mines will have the following water inflows and outflows:

Typical inflows:

- Municipal / Water Board
- River Water
- Ground Water
- Rain Water Runoff
- Other Known Sources

Typical outflows:

- Human consumption
- Discharge to River/Groundwater
- Supply to off-site Third Party
- Evaporative Losses
- Product & Residue Moisture
- Dust suppression
- Other Known Sinks

Of the above inflows and outflows, the following data should be present for all mines and are considered essential for an accurate and complete water balance. This approach is validated by the data collected from the site visits which clearly shows that these two inputs and two outputs represent a major portion of the water balance for each commodity group. A single point was therefore deducted if any of these parameters below were omitted in the water balance.

Essential inflows

- Ground Water
- Rain Water Runoff

Essential outflows

- Discharge to River/Groundwater (as this includes seepage which will generally occur to some degree at all mines)
- Evaporative Losses

Mines were also penalised for significant differences between total inflows and total outflows in their recorded water balance. A single point was therefore subtracted for every ten percent difference between the total inflows and total outflows shown in the water balance.

All the water balances with a score of less than 1 were considered to have too much missing information and too many discrepancies to be used with confidence in the national benchmark setting process. This process resulted in two mines being dropped (1 gold and 1 coal) from the original 39 mines sampled.

Outlier mines with a total water input per ROM ton of more than 4 times the average water usage of that particular commodity were considered to be too high to be representative of the industry in general and were thus discarded. One mine from the "other commodity" category was discarded for this reason.

Outlier mines with a total water input per ROM ton of less than one quarter (25%) of the average water usage of that particular commodity were also considered to be too low to be representative of the industry in general and were thus also discarded. Seven mines (3 coal and 4 "other") were discarded for this reason. For the 3 coal mines removed, (representing three different mining Groups) one was an underground mine without a beneficiation plant and two were opencast mines with beneficiation plants.

Table 2 shows the averages of all the mines per commodity, as well as the averages of the mines with invalid water balances and the averages of mines with valid water balances. From this it can be seen that, for coal and gold, the average of the mines with valid water balances is actually higher than the averages of all the mines. This is due to the fact that the mines with invalid water balances did not include all the water inflows entering the mine water circuits. Using the data from these mines would therefore be incorrect, since it would result in unrealistically low benchmarks.

Table 2: Average total specific water use (per ROM ton) for all mines, as well as those with valid and invalid water balances

Commodity	Total specific water use per ton mined		
	Average of all mines	Average of mines with invalid water balances	Average of mines with valid water balances
Coal	0.79	0.20	1.13
Gold	2.46	0.98	2.67
Platinum	1.68	No invalid mines	1.68
Other	1.23	1.52	1.01

The detailed water usage of the valid and invalid water balances for each commodity is shown in Figure 5 to Figure 8. This process resulted in the removal of data for four of the eleven coal mines, one of the eight gold mines, none of the platinum mines and five of the twelve "other" mines.

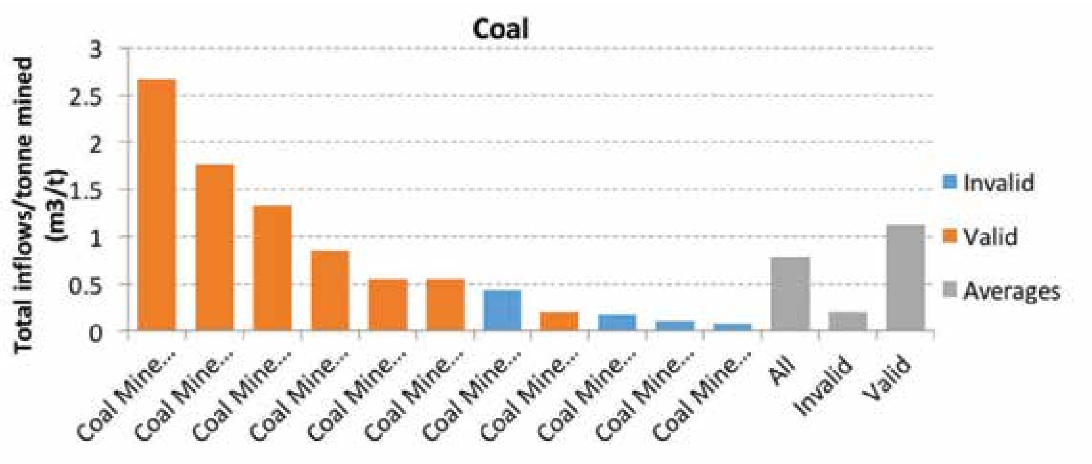

Figure 5: Coal mines with valid and invalid water balances

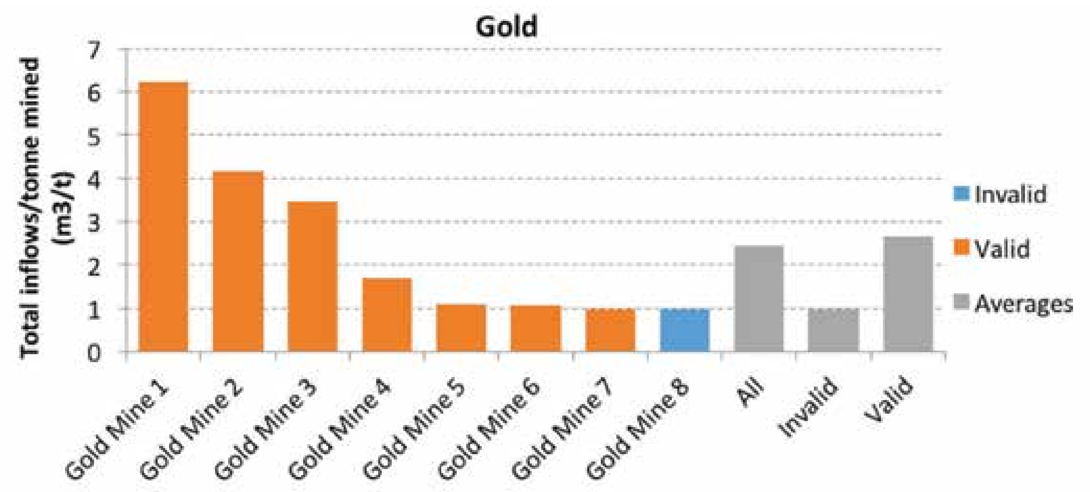

Figure 6: Gold mines with valid and invalid water balances

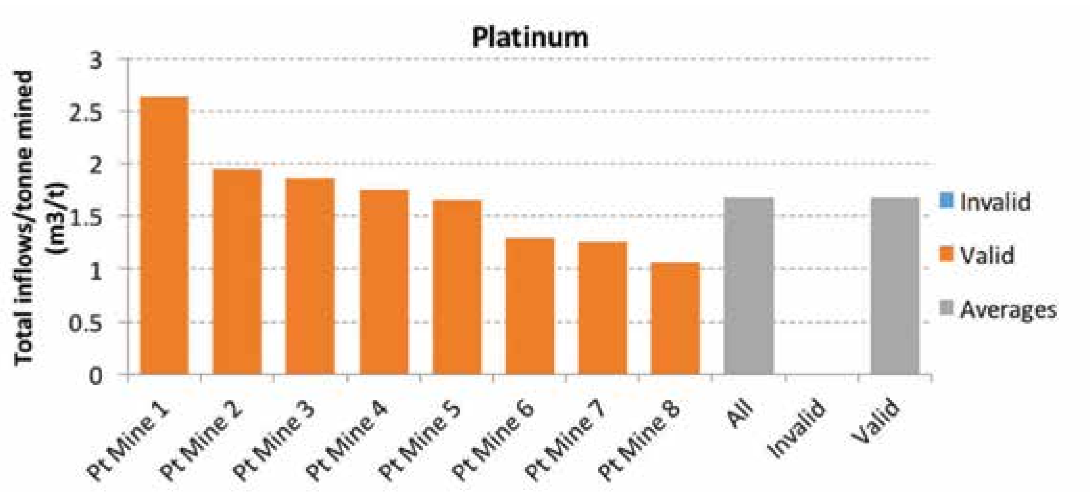

Figure 7: Platinum mines with valid and invalid water balances

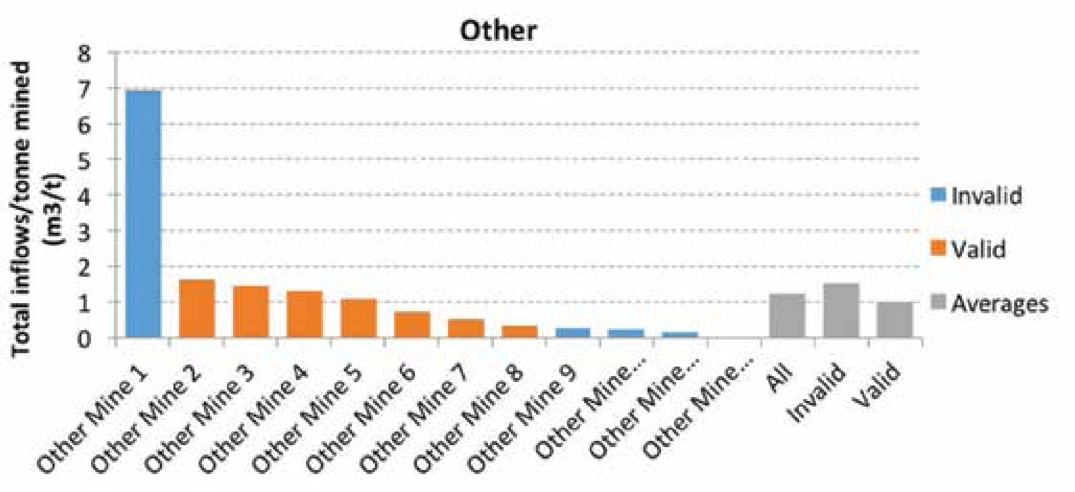

Figure 8: Other mines with valid and invalid water balances

3.2.3. Step 3: Rate Mines in Terms of Water Management Practices

The national water use benchmarks are based on the mines that can demonstrate that effective water management principles and practices are being implemented on the mines (these mines have generally also shown some progress with the implementation of WC/WDM measures, albeit it primarily focused on reducing potable water use). In order to determine the status of water management of the mines, each mine was rated out of 5 (5 being good and 0 being poor) on the five critical aspects listed below:

1) Status (accuracy and completeness) of water balance (weight = 5) (discussed in previous section in detail)

2) Regular monthly update of monitoring data into computerised system (weight = 4)

3) Use of water balance data in water management decision making (weight = 3)

4) Existing WC/WDM plan (weight = 4)

5) Use of DWS BPGs (weight = 2)

The above aspects were rated using the results from the questionnaires that were completed during the site visits. The ratings were then totalled using the relative weights shown in brackets to find a single score out of 5 for each mine related to water management practices. The decision to base the rating on the above five aspects is motivated by the fact that effective WC/WDM is a process that is dependent on the mines having a good computerised water balance, updating it regularly and ensuring that the results from the water balances are used in guiding water management decisions on the mine. Additionally, specific questions relating to the mine's WC/WDM plan (where these existed) and the extent to which the mines apply best practice in their operations were also considered critical in determining whether or not the mines represented good practice with regard to water management.

A discussion of how each of the above aspects was rated is presented in the relevant sections below.

3.2.3.1. Status (accuracy and completeness) of water balance

The status of the water balances were determined as described under section 3.2.2. All mines were given an initial score of 5. Subtractions were then made for missing data and discrepancies.

3.2.3.2. Regular (monthly) update of monitoring data into computerised water balance

The following questions from the questionnaire were used to rate this aspect:

- Is the water balance computerised, and if yes, what type of software is used?
- Is there clear evidence that the water balance is updated at least monthly using new monitoring data?
- Can the mine provide evidence of the frequency and occurrence of calibration of the flow meters installed?

For each yes or not applicable answer, a one was given, and for each no answer a zero was given. The score out of 3 was then scaled to a score out of 5 by dividing it with 3 and multiplying with 5.

3.2.3.3 Use of water balance data in water management decision making

The following questions from the questionnaire were used to rate this aspect:

- Was the mine water balance prepared in accordance with the principles and procedures set out in BPG G2 Water and Salt Balances?
- Is the level of detail in the water balance appropriate as per BPG G2 Water and Salt Balances guidance?
- Is the water balance capable of accommodating changes made to the mine water reticulation system?
- Is the water balance capable of predicting effects of system changes on the mine water balance in order to be used as a management decision tool?

For each yes or not applicable answer, a one was given, and for each no answer a zero was given. The score out of 4 was then scaled to a score out of 5 by dividing it with 4 and multiplying with 5.

3.2.3.4 Existing WC/WDM plan

The following questions from the questionnaire were used to rate this aspect:

- Does the mine have a WC/WDM Plan with clearly defined goals and objectives?
- Was the WC/WDM Guideline used in developing the WC/WDM plan?
- Was BPG H3 Water Reuse and Reclamation used in the development of the WC/WDM plan?
- Have specific actions been identified to achieve WC/WDM objectives?
- Are there documented water quality standards available for all of the major water users on the mine and is there evidence that these standards have been derived from suitable research?

For each yes or not applicable answer, a one was given, and for each no answer a zero was given.

A sixth aspect that was also used to rate the existing WC/WDM plan of each mine was their current target setting methodologies. From the feedback received during the mine visits on this aspect, the current water use target setting methodologies employed by the mines could be divided into five broad categories.

The five categories as well as the score that was given to each category are as follows:

- No targets (score = 1)
- Targets based on allocations contained in water use license (score = 2)
- Targets focussed on reducing potable water usage (score = 3)
- Percentage reduction of water usage based on past water usage (score = 4)
- Specific calculated targets customised for each mine (score = 5)

The scores of the five questions as well as the score for the target setting methodology were then added to give a total score out of 10. This score was scaled to a score out of 5 by dividing it with 2.

3.2.3.5 Use of DWS BPGs

The use of the following DWS Best Practice Guidelines (BPGs) was evaluated:

- BPG A2 Water Management for Mine Residue Deposits
- BPG A3 Water Management in Hydrometallurgical Plants
- BPG A4 Pollution Control Dams
- BPG A5 Water Management for Surface Mines
- BPG A6 Water Management for Underground Mines
- BPG G2 Water and Salt Balances
- BPG G3 Water Monitoring Systems
- BPG H2 Pollution Prevention and Minimisation of Impacts
- BPG H3 Water Reuse and Reclamation

For each yes or not applicable answer, a 1 was given, and for each no answer a 0 was given. The responses on the use of the above nine BPGs, together with the response on the questions as to whether the mine has access to the DWS Best Practice Guidelines were then added to obtain a score out of 10. This score was scaled to a score out of 5 by dividing it with 2.

3.2.4 Step 4: Calculate National Benchmarks

The commodity-based national benchmarks are based on the average value for each benchmark for the top 3 mines of that commodity (based on the rating for general water management described in the previous section for only the mines that have valid water balances). The average benchmark indicator values for these top three mines would be expected to be lower than the benchmark indicator values for all the mines with valid water balances. These values for the indicator "total specific water use" are shown in Table 3 compared to the averages of all the mines as well as the averages of the mines with valid water balances. As can be seen from the table, the averages of the top 3 mines are lower than the averages of the mines with valid water balances, except for the platinum mines (where no mines were removed). For each of the commodity groups, the top 3 mines were therefore used to define the benchmarks.

Due to the many factors that could influence the total specific water use of a mine for a particular commodity, a minimum and maximum value for each benchmark is also specified. This will give the benchmark range and it is based on the minimum and maximum value of the top 3 mines of each commodity. A similar exercise was undertaken for the other key performance indicators.

Table 3: Benchmarks for total specific water use based on top 3 mines (per commodity)

Commodity	Total specific water use per ROM ton (m^3/t)					
	Average of all mines	Average of mines with valid water balances	Average of top 3 mines of each commodity	Benchmark total specific water use		
				Average	Min	Max
Coal	0.79	1.13	0.70	0.70	0.20	1.33
Gold	2.46	2.67	2.09	2.09	1.09	3.47
Platinum	1.68	1.68	1.85	1.85	1.75	1.94
Other	1.23	1.01	0.96	0.96	1.10	1.44

A detailed breakdown of the total specific water use of all mines with valid water balances, as well as the top 3 selected mines, are shown in Figure 9 to Figure 12.

The calculations described above for the key indicator: total specific water use were done for all the different key indicators listed in Section 2 above and the results for all the key indicators are presented in Tables 4 to 7 below for each of the four commodity groupings.

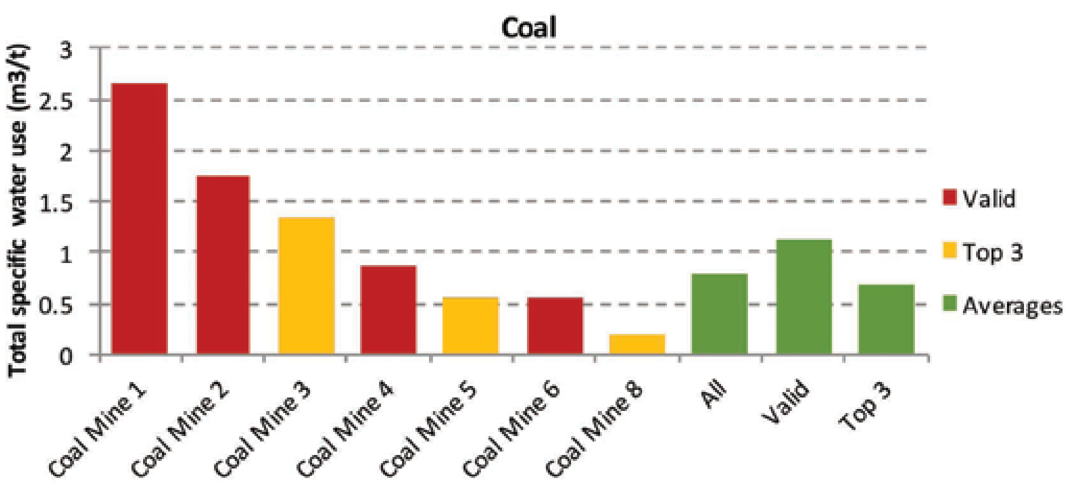

Figure 9: Top 3 selected coal mines

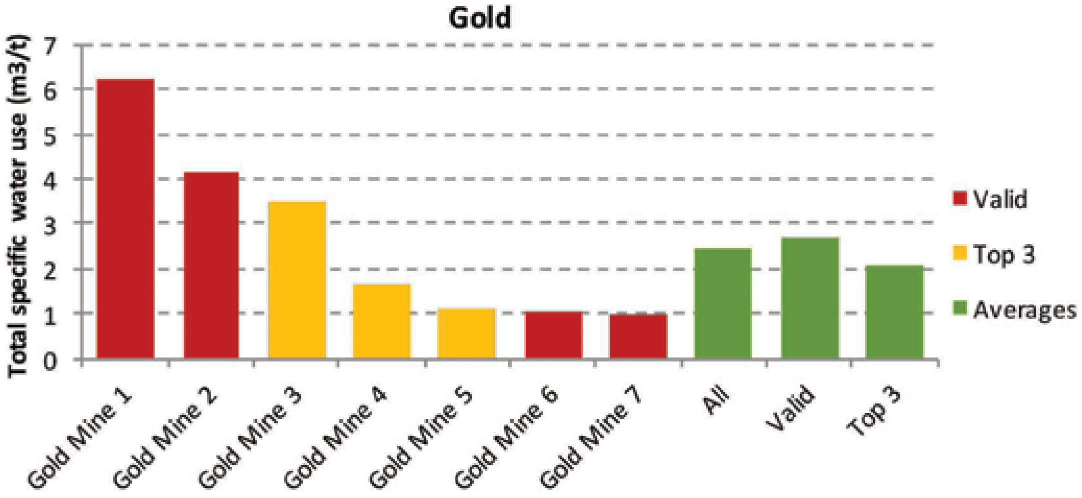

Figure 10: Top 3 selected gold mines

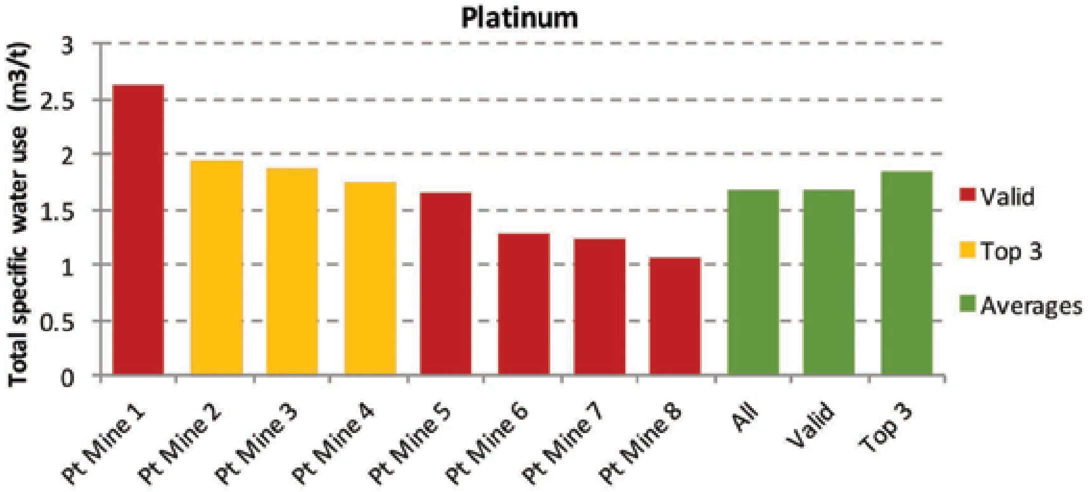

Figure 11: Top 3 selected platinum mines

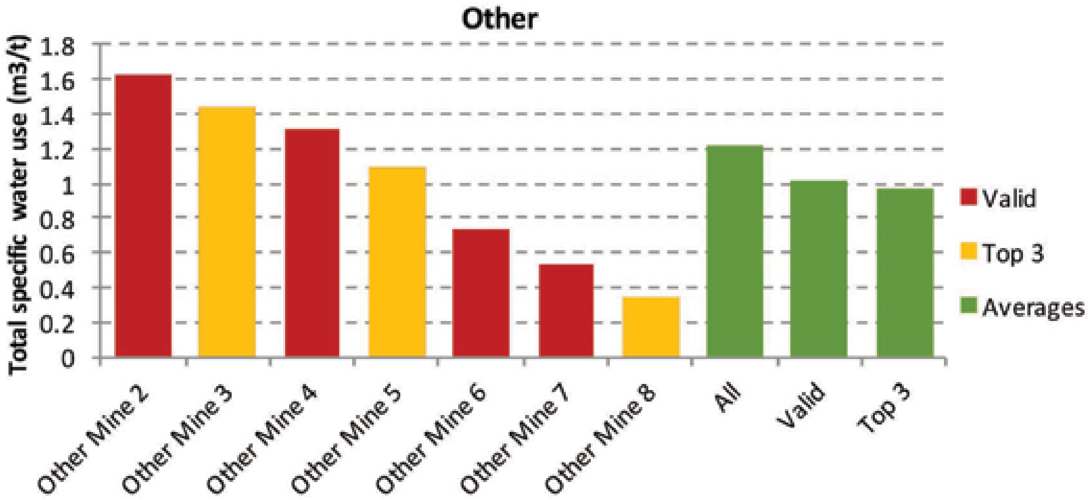

Figure 12: Top 3 selected other mines

Table 4: Water use efficiency indicators for coal mines

Coal		All mines			Valid water balances			Top 3 mines		
	Units	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
Total Mine										
Total Mine – Total specific water use per ROM ton	m^3/t	0.79	0.08	2.67	1.13	0.20	2.67	0.70	0.20	1.33
Total Mine – Consumptive specific water use per ROM ton	m^3/t	0.67	0.05	2.67	0.95	0.20	2.67	0.38	0.20	0.48
Total Mine - % wastewater not recycled	%	63%	11%	100%	63%	11%	100%	72%	15%	100%
Total Mine – Water recycle ratio	%	48%	0%	87%	16%	0%	32%	6%	0%	16%

Table 5: Water use efficiency indicators for gold mines

Gold		All mines			Valid water balances			Top 3 mines		
	Units	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
Total Mine										
Total Mine – Total specific water use per ROM ton	m^3/t	2.46	0.98	6.23	2.67	0.99	6.23	2.09	1.09	3.47
Total Mine – Consumptive specific water use per ROM ton	m^3/t	2.41	0.80	6.23	2.64	0.99	6.23	2.02	1.09	3.47
Total Mine - % waste water not recycled	%	75%	33%	100%	78%	33%	100%	60%	33%	100%
Total Mine – Water recycle ratio	%	39%	9%	74%	40%	9%	74%	18%	9%	25%

Table 6: Water use efficiency indicators for platinum mines

Platinum		All mines			Valid water balances			Top 3 mines		
	Units	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
Total Mine										
Total Mine – Total specific water use per ROM ton	m^3/t	1.68	1.05	2.63	1.68	1.05	2.63	1.85	1.75	1.94
Total Mine – Consumptive specific water use per ROM ton	m^3/t	1.66	1.05	2.63	1.66	1.05	2.63	1.82	1.75	1.86
Total Mine - % waste water not recycled	%	75%	58%	97%	75%	58%	97%	65%	58%	73%
Platinum		All mines			Valid water balances			Top 3 mines		
Total Mine – Water recycle ratio	%	43%	22%	53%	43%	22%	53%	39%	22%	52%

Table 7: Water use efficiency indicators for other mines

Other		All mines			Valid water balances			Top 3 mines		
	Units	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
Total Mine										
Total Mine – Total specific water use per ROM ton	m³/t	1.23	0.02	6.95	1.01	0.35	1.63	0.96	0.35	1.44
Total Mine – Consumptive specific water use per ROM ton	m³/t	1.14	0.01	6.95	0.87	0.31	1.63	0.65	0.31	0.85
Total Mine - % waste water not recycled	%	60%	12%	100%	59%	20%	100%	52%	30%	81%
Total Mine – Water recycle ratio	%	62%	17%	79%	57%	17%	74%	45%	17%	58%

An assessment was made of the three mines in each commodity group that were selected as the top 3 mines in order to determine the nature of mining and beneficiation at these top mines as well as to determine what type of water conservation actions and measures had been implemented at these mines and which could have resulted in them being selected as the top 3 mines. It must again be stressed that the selection of the top 3 mines was an objective exercise based on a standardised scoring system for a wide range of aspects that contribute to water management on a mine.

3.2.4.1 Top 3 coal mines

The top 3 coal mines represented different types of mining operations. One was an underground mine without a beneficiation plant while two were opencast mines with beneficiation plants. None of these mines had prepared a separate stand-alone WC/WDM plan. The types of WC/WDM actions found at the top three coal mines included the following:

- Focus on reduction of potable water intake;
- Focus on increasing the reuse and recycle of waste water streams;
- Water use efficiency targets were set externally and not on the mines themselves;
- Two mines had access to desalination plants to treat waste water to enable it to be reused; and
- The DWS WC/WDM guideline and BPG H3 were not being used on any of the mines as the primary focus was on potable use reduction.

3.2.4.2. Top 3 gold mines

The top 3 gold mines all employ underground mining techniques and all three have beneficiation plants. Two mines had stand-alone WC/WDM plans while one did not. All three mines had internal water use targets and regularly measure and report actual use versus targets. The types of WC/WDM actions found at the top three gold mines included the following:

- Focus on reduction of potable water intake;
- Replace potable water with fissure (ground water) water in the process plant and fridge plants;
- Eliminate leaking pipelines, use pressure reducing valves, install low flow showers;
- Educate and train staff on WC/WDM principles;
- Appoint water champions who have responsibility for implementing WC/WDM measures, measuring
- and reporting on the success of these measures;
- Review and assess water management systems against the DWS BPGs;
- Ensure that all discharges meet standards;
- Design for zero overflows from pollution control dams;
- Use a computerised water balance model with simulation capability to evaluate WC/WDM measures;
- Adapt management systems to ensure that the WC/WDM strategy is implemented;
- Review water use targets annually;
- No desalination plants employed;
- Plans to intercept, treat and reuse seepage from pollution control dams and tailings disposal facilities; and
- Detailed post-closure geohydrological, hydrological and geochemical predictive models are in place and being regularly calibrated

3.2.4.3 Top 3 platinum mines

The top 3 platinum mines all employ underground mining techniques and all three have beneficiation plants. Two mines had stand-alone WC/WDM plans while one did not. All three mines had internal water use targets and regularly measure and report actual use versus targets, primarily focused on potable water use reduction. The types of WC/WDM actions found at the top three platinum mines included the following:

- Focus on reduction of potable water intake;
- Two mines use a computerised water balance model with simulation capability to evaluate WC/WDM measures;
- Water use targets are either set using the WETT tool or on an arbitrary annual percentage reduction;
- Aim for zero potable water use and zero water discharge;
- Review water use targets annually;
- One mine has access to a desalination plant while the other two only apply suspended solids removal as a water treatment technology;
- Reduce pollution at source by intercepting, treating and reusing seepage;
- Lining of all pollution control dams to minimise seepage losses; and

- Eliminate or reduce environmental discharges by effective management of the overall mine water balance.

3.2.4.4. Top 3 other mines

The top 3 other mines included two mines that employed opencast mining methods while one was an underground mine. All three mines had beneficiation plants. Only one mine had a stand-alone WC/WDM plan but did not use the DWS WC/WDM guideline in developing this plan. The types of WC/WDM actions found at the top three “other” mines included the following:

- Primary focus was on eliminating environmental discharges;
- No WC/WDM targets were documented;
- WC/WDM targets were being continuously sought but tended to be more on an ad-hoc basis rather than as part of an integrated WC/WDM strategy or plan; and
- One mine was planning to implement tailings disposal facility seepage interception and reuse systems.

3.2.5. Step 5: Determine national benchmark ranges

The average national benchmark values were derived using the process outlined in Sections 3.2.1 to 3.2.4 above shown in Table 3. It is recognised that the actual specific water use at each mine is dependent on many factors, including those that were previously identified and listed in the variables matrix (attached as Appendix B) and that the effect of these variables needs to be considered when defining the range (minimum to maximum) for the various water use benchmarks.

As the sample of mines visited in this project does not represent the full extent of possibilities for all the variables in the variables matrix, a water balance simulation tool was developed that was capable of evaluating the effects these variables would have on the key performance indicators. A detailed description of this water balance model is provided in Appendix C. The water balance model was configured to allow it to run in a probabilistic (Monte Carlo) mode, with random sampling of all the key variables, in order to simulate the range in the values for the key performance indicators that could be expected across the various commodities. The results from these simulations were then statistically evaluated in order to identify the expected standard deviations of the data for each of the key performance indicators.

As constructed, the generic water balance model was capable of evaluating, amongst others, the effect of the following variables described in the variables matrix
:

- Climate (rainfall & evaporation)
- Commodity being mined
- Groundwater make to the water balance
- Extent of mine cooling required
- Type of mining (opencast or underground)
- Opencast pit size
- Opencast pit rehabilitation rate and efficiency
- Depth of mining
- Presence of beneficiation plant
- Percentage ore to waste rock

- Tailings density
- Tailings dam rise rate
- Tailings dam pool size
- Product moisture content
- Water use for dust suppression
- Consumptive water use per worker
- Sewage water recycle rate

It can therefore be reasonably confidently stated that the effects of the parameters contained in the variables matrix were properly evaluated and considered. The output from the exercise to consider the effect of the variables matrix parameters was to determine the standard deviation around the water use efficiency indicators for the average mine condition that could be expected due to the effect of these variables.

Table 8: Standard deviation of water use efficiency 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%

The effect of a single standard deviation above and below the averages for the top 3 mines was then evaluated in order to define the range for the benchmarks for the different key performance indicators. These national water use efficiency benchmarks are shown in Tables 9 to 12 below.

The benchmark for each water use efficiency indicator reported in the tables below (per commodity) is based on the averages of the top 3 selected mines for each commodity (reported in previous section). The minimum and maximum values that constitute the range of the benchmarks are based on the application of a single standard deviation of each indicator to allow for the effects of the variables described in the variables matrix.

Table 9: National water use efficiency benchmarks and ranges for coal mines

Coal Mines	Units	Benchmark	Min (1x$\sigma\sigma$)	Max (1x$\sigma\sigma$)
Total Mine				
Total Mine - Total specific water use per ROM ton	m^3/t	0.70	0.50	0.89
Total Mine - Consumptive specific water use per ROM ton	m^3/t	0.38	0.20	0.55
Total Mine - % waste water not recycled	%	72%	60%	84%
Total Mine - Water recycle ratio	%	6%	0%	38%

Table 10: National water use efficiency benchmarks and ranges for gold mines

Gold Mines	Units	Benchmark	Min (1xσσ)	Max (1xσσ)
Total Mine				
Total Mine - Total specific water use per ROM ton	m^3/t	2.09	1.60	2.57
Total Mine - Consumptive specific water use per ROM ton	m^3/t	2.02	1.52	2.51
Total Mine - % waste water not recycled	%	60%	47%	73%
Total Mine - Water recycle ratio	%	18%	0%	50%

Table 11: National water use efficiency benchmarks and ranges for platinum mines

Platinum Mines	Units	Benchmark	Min (1xσσ)	Max (1xσσ)
Total Mine				
Total Mine - Total specific water use per ROM ton	m^3/t	1.85	1.64	2.07
Total Mine - Consumptive specific water use per ROM ton	m^3/t	1.82	1.60	2.04
Total Mine - % waste water not recycled	%	65%	42%	78%
Total Mine - Water recycle ratio	%	39%	2%	76%

Table 12: National water use efficiency benchmarks and ranges for other mines

Other Mines	Units	Benchmark	Min (1xσσ)	Max (1xσσ)
Total Mine				
Total Mine - Total specific water use per ROM ton	m^3/t	0.96	0.76	1.16
Total Mine - Consumptive specific water use per ROM ton	m^3/t	0.65	0.45	0.86
Total Mine - % waste water not recycled	%	52%	39%	65%
Total Mine - Water recycle ratio	%	45%	10%	80%

The national total and consumptive specific water use efficiency benchmarks are also shown graphically in Figure 13 below.

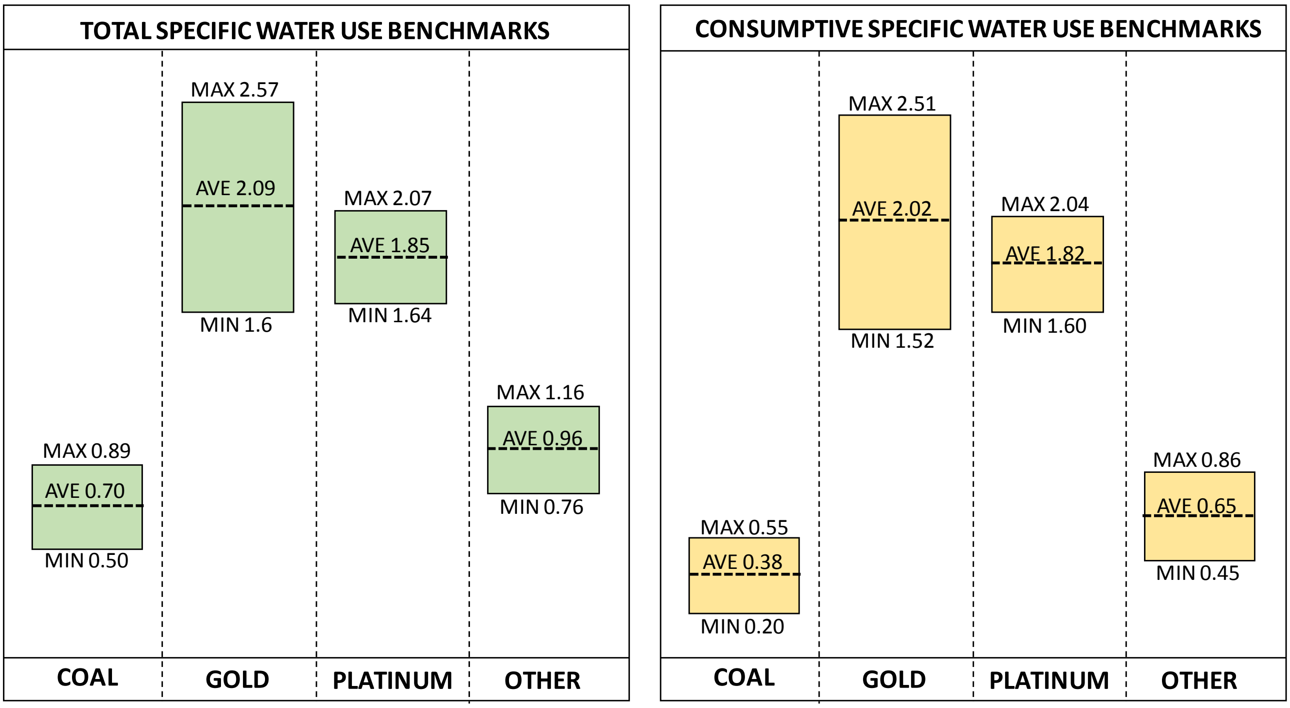

Figure 13: National specific water use benchmarks for both total specific water use and consumptive specific water use

4. CONCLUSION

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 industrfy. 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 WCWDM 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.

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APPENDIX A
KEY INDICATOR VALUES FOR ALL MINES

Table A1: Key indicators (Total Mine)

Mine	Commodity	Total water input	Consumptive use	Wastewater lost	Total water input per ROM ton ore	Consumptive use per ROM ton ore	Percentage of waste water not recycled	Water recycle ratio
		m³/d	m³/d	m³/d	m³/t	m³/t	%	%
Mine 03	Coal	18 139	6 074	6 074	1.33	0.45	100%	0%
Mine 04	Coal	43 658	26 658	3 000	0.86	0.52	11%	0%
Mine 05	Coal	1 592	1 032	363	0.08	0.05	35%	0%
Mine 06	Coal	40 289	40 289	40 289	2.67	2.67	100%	22%
Mine 07	Coal	18 846	18 846	2 899	0.20	0.20	15%	16%
Mine 08	Coal	4 126	4 126	3 830	1.76	1.76	93%	30%
Mine 09	Coal	601	601	601	0.10	0.10	100%	87%
Mine 10	Coal	22 342	19 342	19 342	0.56	0.48	100%	0%
Mine 11	Coal	5 133	5 133	4 933	0.18	0.18	96%	0%
Mine 12	Coal	14 048	14 048	3 242	0.43	0.43	23%	68%
Mine 13	Coal	16 149	16 149	3 200	0.55	0.55	20%	32%
Mine 16	Gold	49 344	49 344	16 445	1.09	1.09	33%	25%
Mine 17	Gold	22 501	22 501	10 539	3.47	3.47	47%	20%
Mine 18	Gold	13 029	10 621	6 285	0.98	0.80	59%	29%
Mine 19	Gold	17 462	15 393	15 393	1.69	1.49	100%	9%
Mine 20	Gold	11 801	11 801	11 801	0.99	0.99	100%	74%
Mine 21	Gold	77 547	77 547	59 060	4.15	4.15	76%	13%
Mine 22	Gold	20 871	20 871	17 988	6.23	6.23	86%	19%
Mine 23	Gold	2 416	2 415	2 415	1.07	1.07	100%	48%
Mine 01	Other	1 092	1 092	1 092	0.26	0.26	100%	62%
Mine 02	Other	5 367	5 233	5 233	1.31	1.27	100%	65%
Mine 14	Other	6 949	6 949	3 704	0.17	0.17	53%	57%
Mine 15	Other	4 610	4 610	1 338	0.53	0.53	29%	47%
Mine 24	Other	2 217	767	250	0.02	0.01	33%	76%
Mine 25	Other	37 152	33 432	27 144	0.35	0.31	81%	17%
Mine 26	Other	59 761	35 071	21 555	1.44	0.85	61%	58%
Mine 27	Other	5 222	5 222	1 040	1.63	1.63	20%	57%
Mine 28	Other	2 946	2 922	2 813	0.74	0.73	96%	74%
Mine 29	Other	84 621	61 969	17 703	1.10	0.80	29%	48%
Mine 30	Other	685	640	75	0.23	0.21	12%	79%
Mine 31	Other	68 761	68 761	68 761	6.95	6.95	100%	23%
Mine 32	Platinum	14 693	14 693	8 562	1.86	1.86	58%	52%
Mine 33	Platinum	28 606	27 257	17 237	1.94	1.85	63%	35%
Mine 34	Platinum	60 281	60 281	46 412	2.63	2.63	77%	42%
Mine 35	Platinum	43 730	43 730	42 588	1.29	1.29	97%	34%
Mine 36	Platinum	5 908	5 908	5 329	1.25	1.25	90%	41%
Mine 37	Platinum	14 945	14 945	10 886	1.75	1.75	73%	22%
Mine 38	Platinum	14 571	14 556	9 723	1.05	1.05	67%	50%
Mine 39	Platinum	13 826	12 981	9 561	1.65	1.55	74%	53%

Table A2: Key indicators (Mining)

Mine	Commodity	Total water input	Consumptive use	Total water input per ROM ton ore	Consumptive use per ROM ton ore
		m³/d	m³/d	m³/t	m³/t
Mine 03	Coal	14 787	-	1.08	0.00
Mine 04	Coal	-	-	0.00	0.00
Mine 05	Coal	1 592	1 032	0.08	0.05
Mine 06	Coal	-	-	0.00	0.00
Mine 07	Coal	8 818	1 421	0.09	0.02
Mine 08	Coal	301	301	0.13	0.13
Mine 09	Coal	615	615	0.10	0.10
Mine 10	Coal	7 138	7 138	0.18	0.18
Mine 11	Coal	4 624	4 624	0.16	0.16
Mine 12	Coal	9 649	9 649	0.30	0.30
Mine 13	Coal	-	-	0.00	0.00
Mine 16	Gold	9 806	9 806	0.22	0.22
Mine 17	Gold	31 700	7 135	4.89	1.10
Mine 18	Gold	14 544	14 544	1.09	1.09
Mine 19	Gold	6 075	-	0.59	0.00
Mine 20	Gold	3 990	-	0.33	0.00
Mine 21	Gold	62 255	62 255	3.34	3.34
Mine 22	Gold	10 899	10 899	3.25	3.25
Mine 23	Gold	2 416	2 415	1.07	1.07
Mine 01	Other	2 958	2 958	0.71	0.71
Mine 02	Other	3 318	3 318	0.81	0.81
Mine 14	Other	2 020	4	0.05	0.00
Mine 15	Other	1 374	1 374	0.16	0.16
Mine 24	Other	2 123	308	0.02	0.00
Mine 25	Other	37 152	4 080	0.35	0.04
Mine 26	Other	4 318	-	0.10	0.00
Mine 27	Other	2 303	303	0.72	0.09
Mine 28	Other	3 112	844	0.78	0.21
Mine 29	Other	8 020	1 149	0.10	0.01
Mine 30	Other	-	-	0.00	0.00
Mine 31	Other	62 679	62 679	6.33	6.33
Mine 32	Platinum	10 662	3 854	1.35	0.49
Mine 33	Platinum	12 003	5 126	0.82	0.35
Mine 34	Platinum	22 295	10 056	0.97	0.44
Mine 35	Platinum	21 047	18 475	0.62	0.55
Mine 36	Platinum	2 541	2 237	0.54	0.47
Mine 37	Platinum	12 798	4 545	1.50	0.53
Mine 38	Platinum	9 807	3 924	0.71	0.28
Mine 39	Platinum	3 976	1 869	0.47	0.22

Table A3: Key indicators (Beneficiation)

Mine	Commodity	Total water input	Consumptive use	Total water input per ROM ton ore	Consumptive use per ROM ton ore
		m^3/d	m^3/d	m^3/t	m^3/t
Mine 03	Coal	-	-	0.00	0.00
Mine 04	Coal	-	-	0.00	0.00
Mine 05	Coal	-	-	0.00	0.00
Mine 06	Coal	11 790	11 790	0.78	0.78
Mine 07	Coal	27 790	27 790	0.30	0.30
Mine 08	Coal	2 119	2 119	0.91	0.91
Mine 09	Coal	2 111	2 111	0.36	0.36
Mine 10	Coal	2 250	2 250	0.06	0.06
Mine 11	Coal	-	-	0.00	0.00
Mine 12	Coal	10 782	10 782	0.33	0.33
Mine 13	Coal	20 371	20 371	0.69	0.69
Mine 16	Gold	78 536	62 497	1.74	1.38
Mine 17	Gold	14 313	14 313	2.21	2.21
Mine 18	Gold	13 470	13 384	1.01	1.00
Mine 19	Gold	12 782	12 782	1.39	1.39
Mine 20	Gold	8 498	8 498	0.71	0.71
Mine 21	Gold	19 674	19 674	1.05	1.05
Mine 22	Gold	11 518	11 518	7.44	7.44
Mine 23	Gold	-	-	0.00	0.00
Mine 01	Other	1 999	1 999	0.61	0.61
Mine 02	Other	1 980	1 980	0.48	0.48
Mine 14	Other	7 666	7 294	1.00	0.95
Mine 15	Other	31 253	31 253	3.59	3.59
Mine 24	Other	588	588	0.00	0.00
Mine 25	Other	9 480	9 480	0.09	0.09
Mine 26	Other	88 716	88 716	2.23	2.23
Mine 27	Other	3 063	3 063	0.95	0.95
Mine 28	Other	3 963	3 670	0.94	0.87
Mine 29	Other	76 914	69 271	1.05	0.94
Mine 30	Other	-	-	0.00	0.00
Mine 31	Other	32 792	12 543	3.31	1.27
Mine 32	Platinum	10 783	10 783	1.37	1.37
Mine 33	Platinum	21 411	21 411	1.52	1.52
Mine 34	Platinum	76 566	76 566	2.17	2.17
Mine 35	Platinum	60 501	60 501	1.79	1.79
Mine 36	Platinum	6 727	6 496	1.42	1.37
Mine 37	Platinum	13 472	13 472	1.50	1.50
Mine 38	Platinum	16 418	16 021	1.19	1.16
Mine 39	Platinum	17 724	16 864	2.11	2.01

Table A4: Key indicators (Residue disposal)

Mine	Commodity	Total water input	Consumptive use	Total water input per ROM ton ore	Consumptive use per ROM ton ore
		m³/d	m³/d	m³/t	m³/t
Mine 03	Coal	-	-	0.00	0.00
Mine 04	Coal	-	-	0.00	0.00
Mine 05	Coal	-	-	0.00	0.00
Mine 06	Coal	1 396	1 396	0.40	0.40
Mine 07	Coal	14 686	11 151	0.16	0.12
Mine 08	Coal	2 180	450	0.93	0.19
Mine 09	Coal	2 425	314	0.41	0.05
Mine 10	Coal	-	-	0.00	0.00
Mine 11	Coal	-	-	0.00	0.00
Mine 12	Coal	5 372	533	2.83	0.28
Mine 13	Coal	18 315	10 793	0.62	0.37
Mine 16	Gold	46 390	46 390	1.28	1.28
Mine 17	Gold	16 456	10 932	2.76	1.83
Mine 18	Gold	16 946	11 686	1.27	0.88
Mine 19	Gold	13 757	13 757	1.49	1.49
Mine 20	Gold	8 335	8 335	0.70	0.70
Mine 21	Gold	10 191	3 053	0.55	0.16
Mine 22	Gold	19 541	16 711	5.83	4.99
Mine 23	Gold	-	-	0.00	0.00
Mine 01	Other	150	150	0.17	0.17
Mine 02	Other	2 645	156	0.64	0.04
Mine 14	Other	8 411	5 614	1.10	0.73
Mine 15	Other	38 720	38 720	21.12	21.12
Mine 24	Other	77	27	0.00	0.00
Mine 25	Other	18 840	11 064	0.18	0.10
Mine 26	Other	108 302	33 321	2.73	0.84
Mine 27	Other	944	802	0.29	0.25
Mine 28	Other	2 286	1 021	0.54	0.24
Mine 29	Other	103 103	45 846	3.80	1.69
Mine 30	Other	-	-	0.00	0.00
Mine 31	Other	239	239	0.02	0.02
Mine 32	Platinum	14 976	7 511	1.90	0.95
Mine 33	Platinum	26 770	17 426	2.20	1.43
Mine 34	Platinum	66 604	26 008	2.05	0.80
Mine 35	Platinum	44 321	21 621	1.31	0.64
Mine 36	Platinum	6 327	2 452	1.34	0.52
Mine 37	Platinum	8 906	4 670	1.66	0.87
Mine 38	Platinum	16 340	8 390	1.97	1.01
Mine 39	Platinum	15 675	8 343	3.12	1.66

APPENDIX B
VARIABLES MATRIX

B1 Introduction

The extent to which water conservation (WC) and water demand management (WDM) measures which 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 consideredwhen 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.

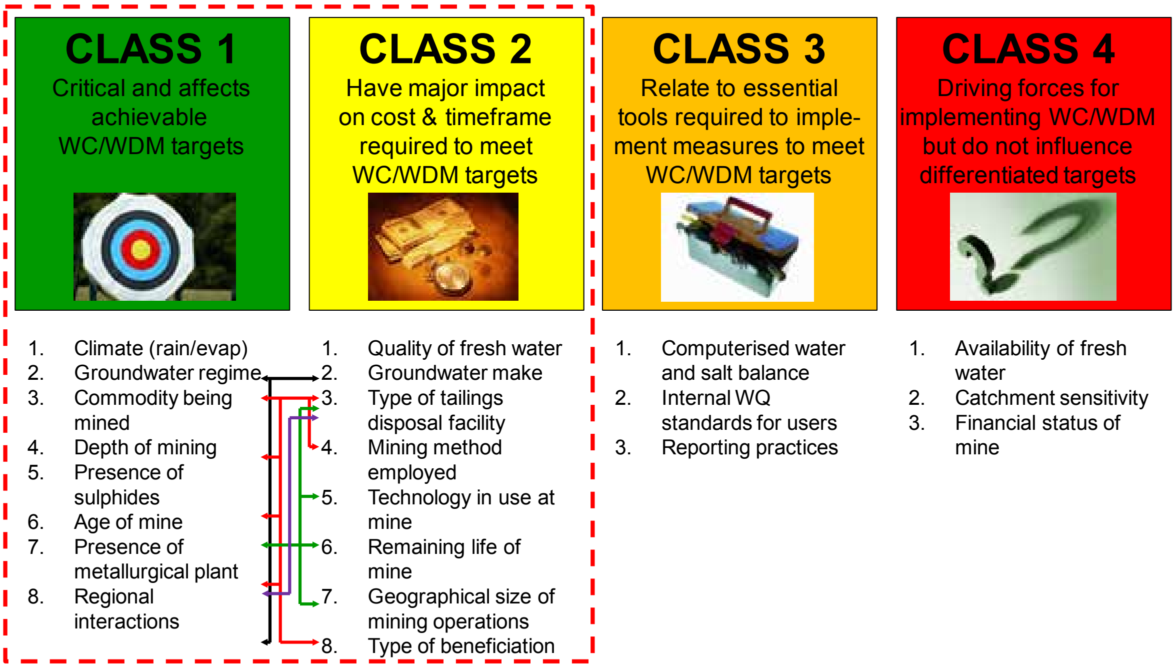

Figure B1: Variables affecting WC/WDM

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).

Variable Description	Comment
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.
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 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 life 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.
Variable Description	**Comment**
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

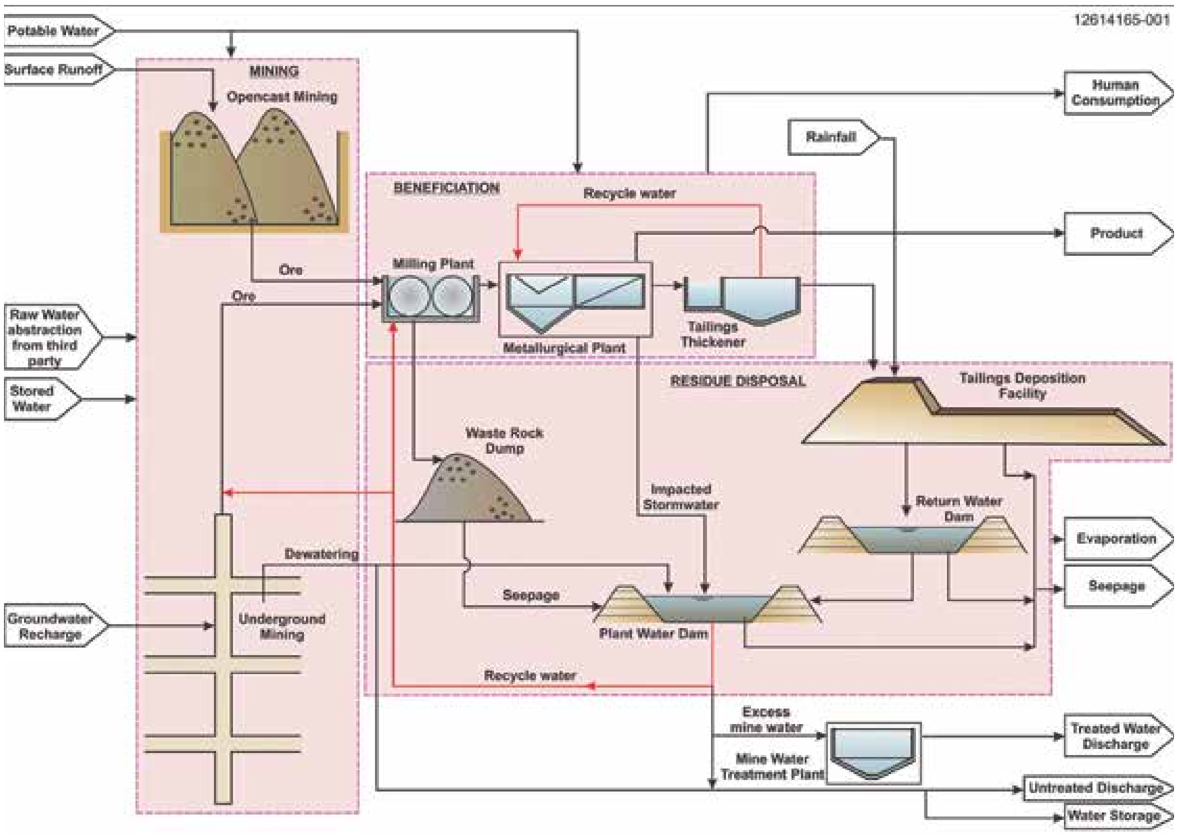

Figure C1: Total mine water balance diagram

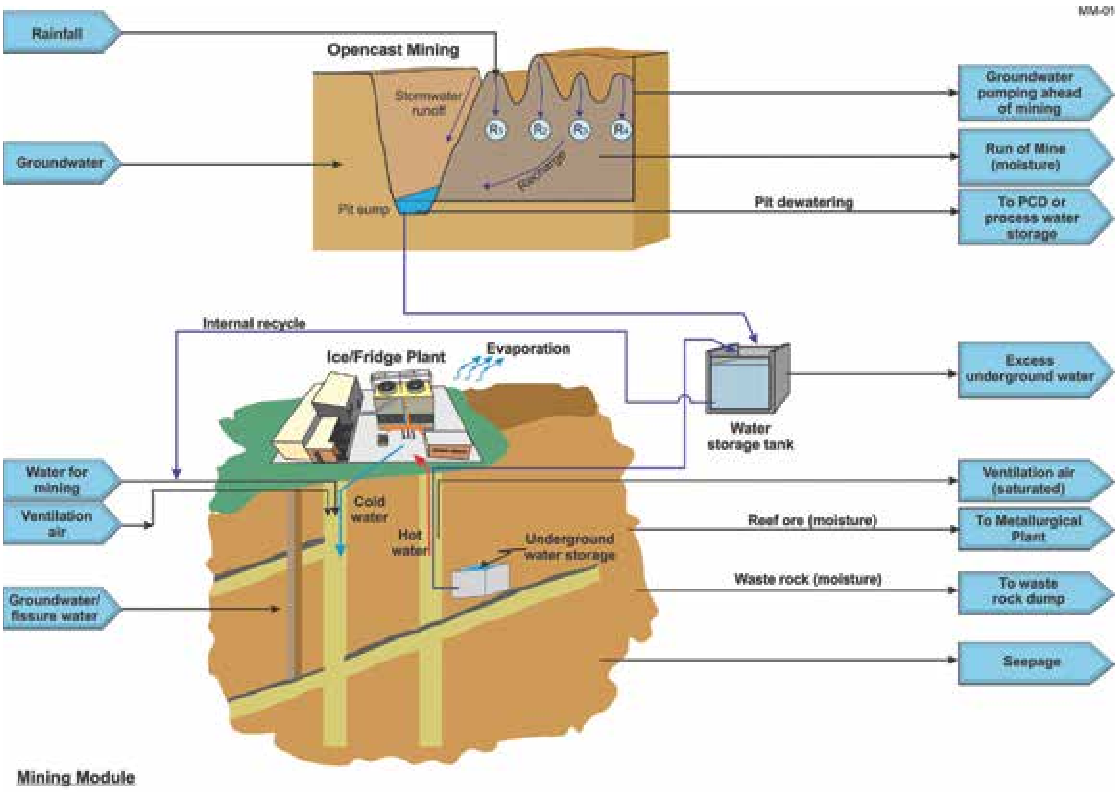

Figure C2: Mining section water balance diagram

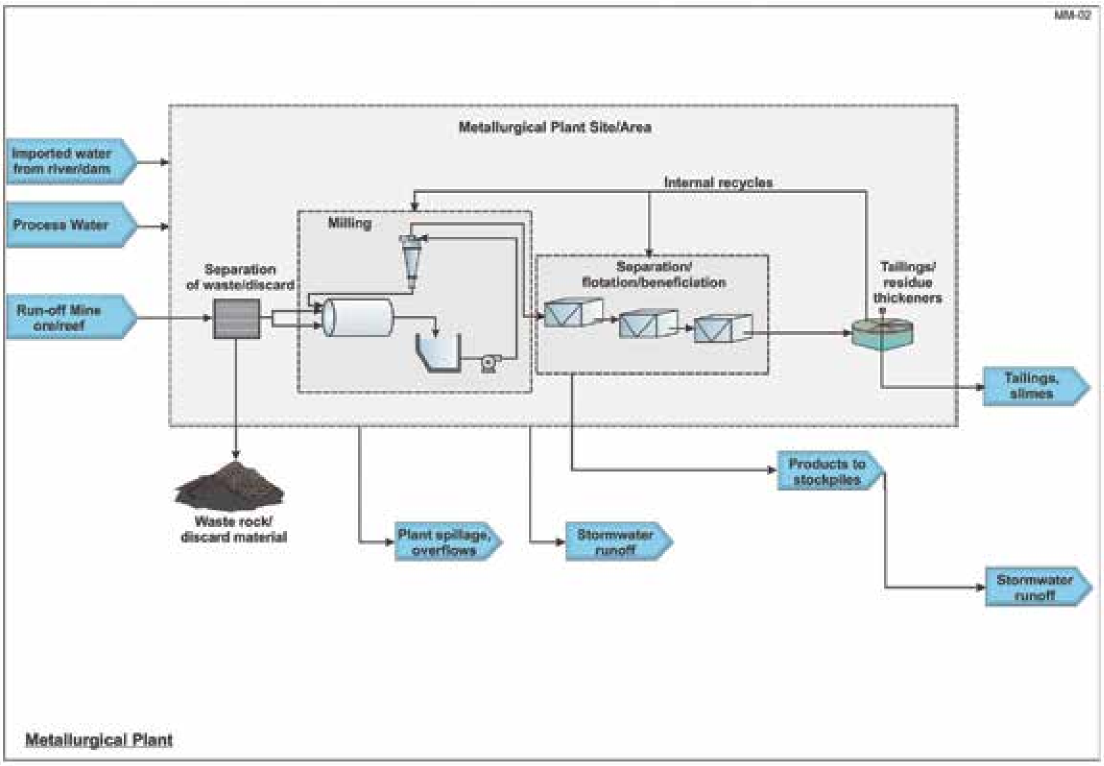

Figure C3: Beneficiation section water balance diagram

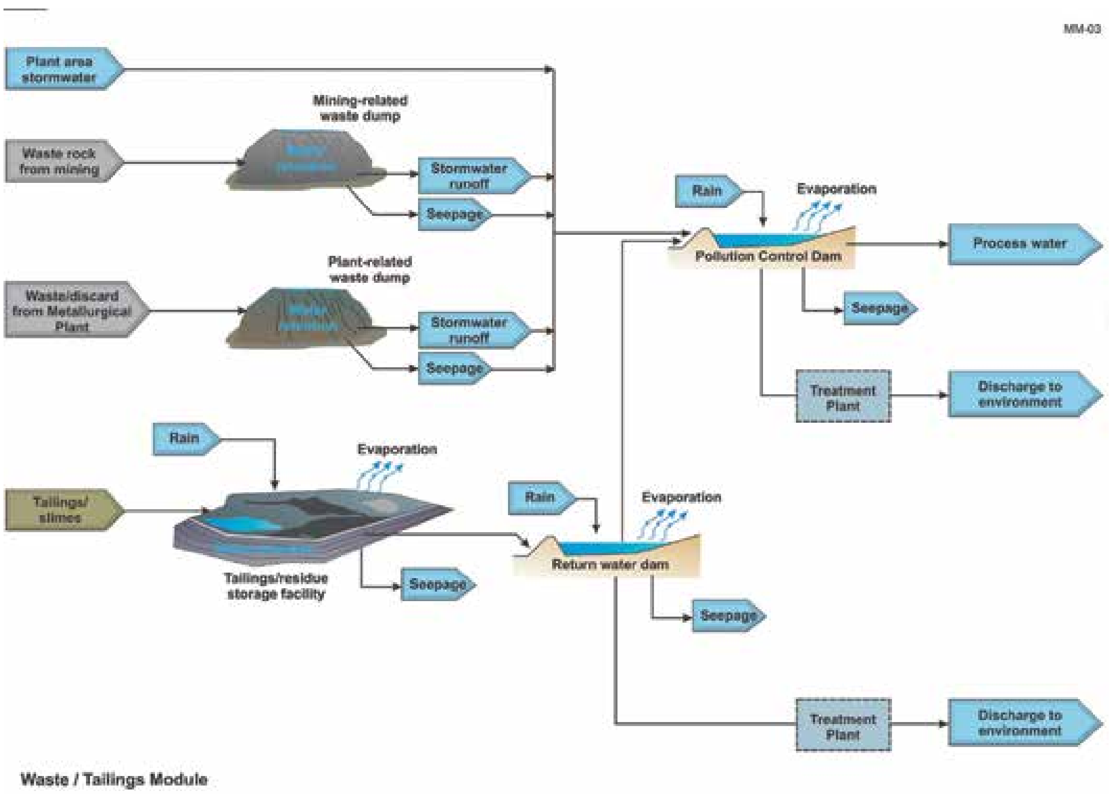

Figure C4: Residue disposal section water balance diagram

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 (m³/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)

Inflow/outflow (m^3/year)	Type	Description of calculations	Influenced by these variables
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
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

Inflow/outflow (m^3/ year)	Type	Description of calculations	Influenced by these variables
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)
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

Inflow/outflow (m^3/ year)	Type	Description of calculations	Influenced by these variables
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
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)

Inflow/outflow (m^3/year)	Type	Description of calculations	Influenced by these variables
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)
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

Inflow/outflow (m^3/ year)	Type	Description of calculations	Influenced by these variables
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
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

Inflow/outflow (m^3/year)	Type	Description of calculations	Influenced by these variables
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

Inflow/outflow (m^3/year)	Type	Description of calculations	Influenced by these variables
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)

Inflow/outflow (m^3/year)	Type	Description of calculations	Influenced by these variables
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			
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.

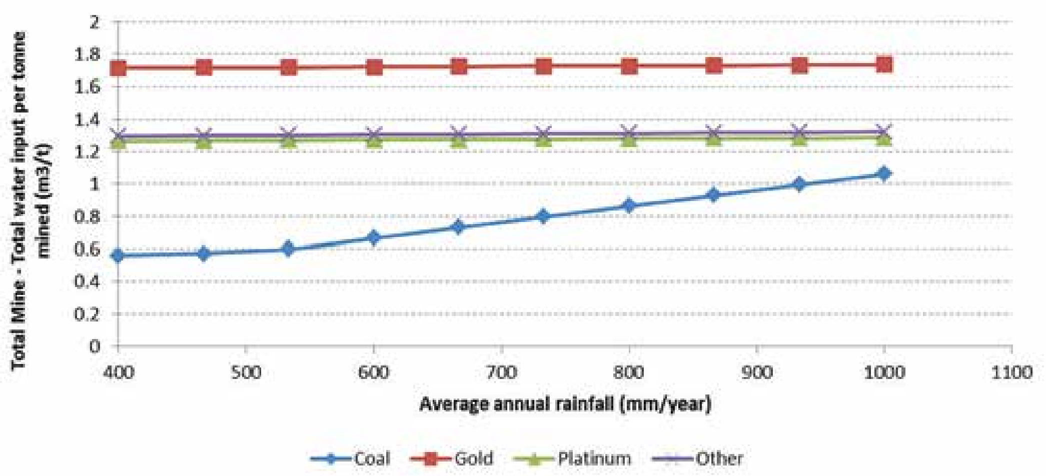

Figure C5: Effect of annual rainfall on total water use efficiency

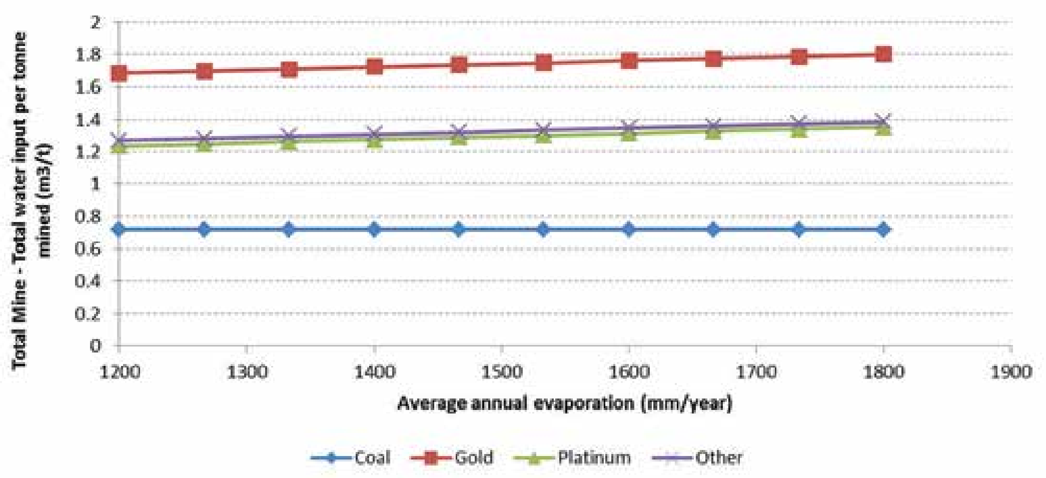

Figure C6: Effect of annual evaporation on total water use efficiency

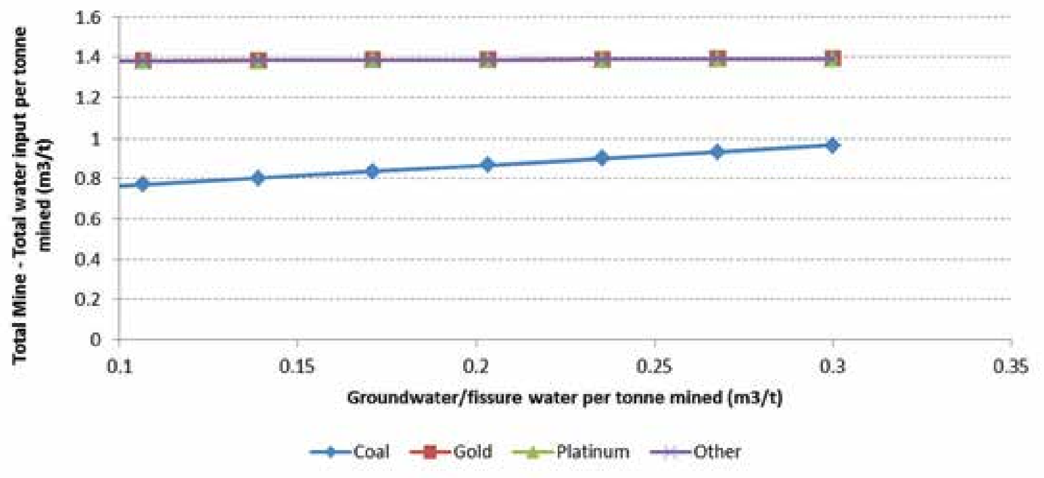

Figure C7: Effect of ground water / fissure water make on total water use efficiency

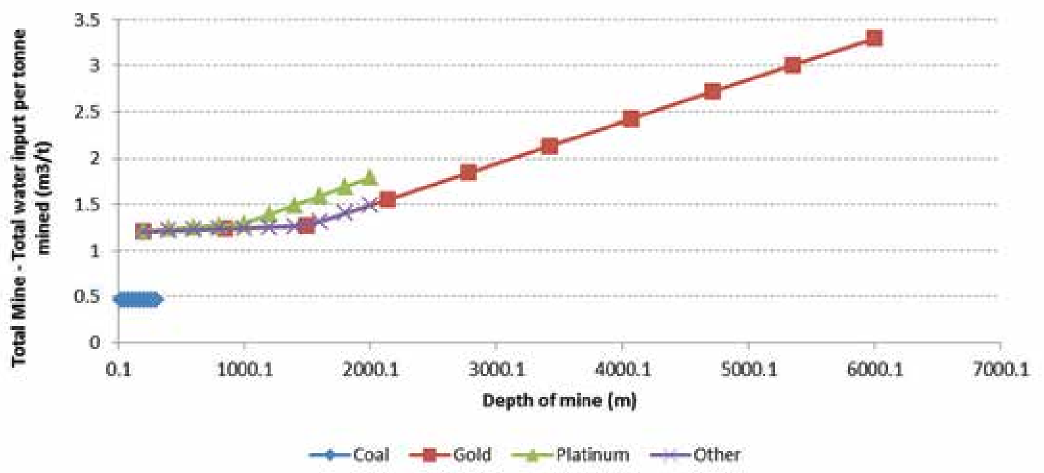

Figure C8: Effect of depth of underground mines on total water use efficiency

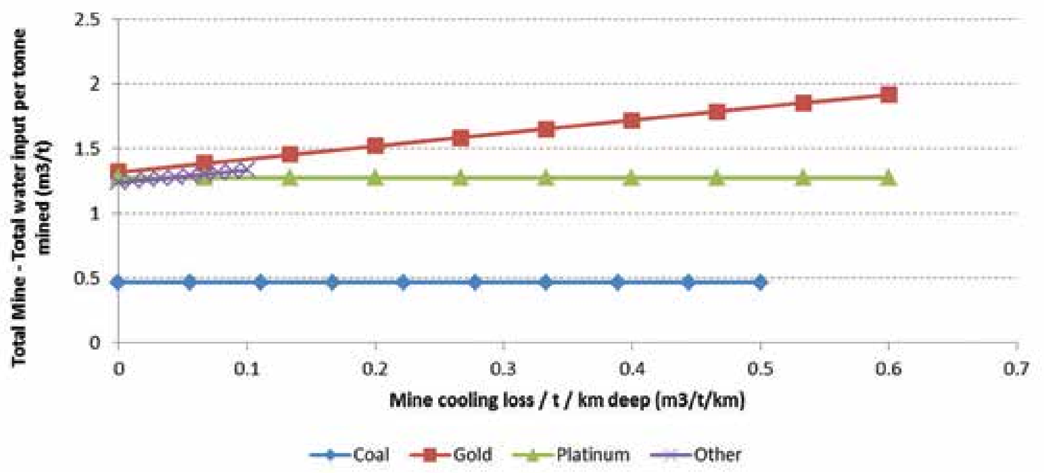

Figure C9: Effect of depth of mine cooling water requirement on total water use efficiency

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 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

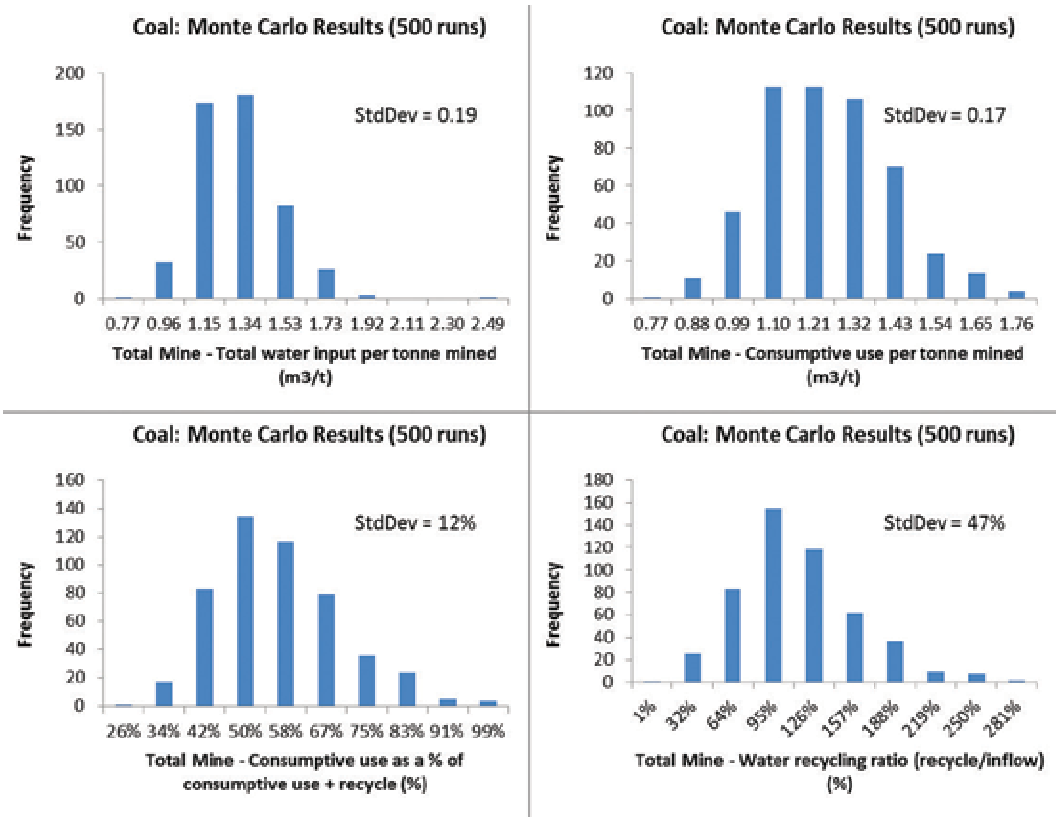

Figure C10: Effect of variations on total mine water balance key indicators

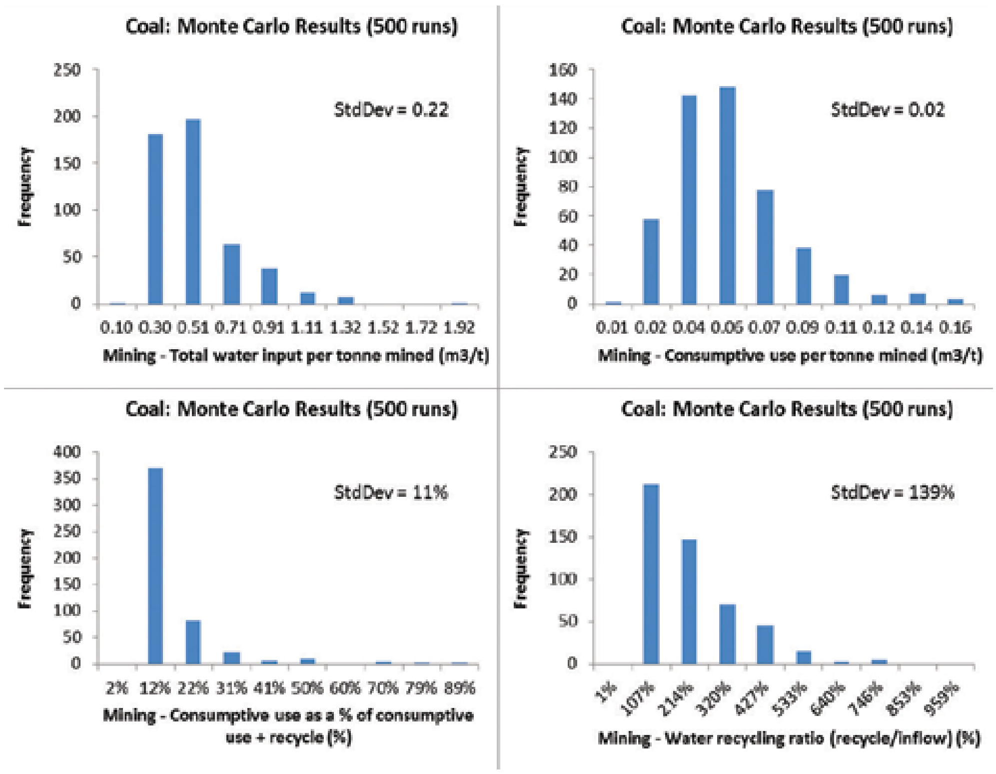

Figure C11: Effect of variations on mining water balance key indicators

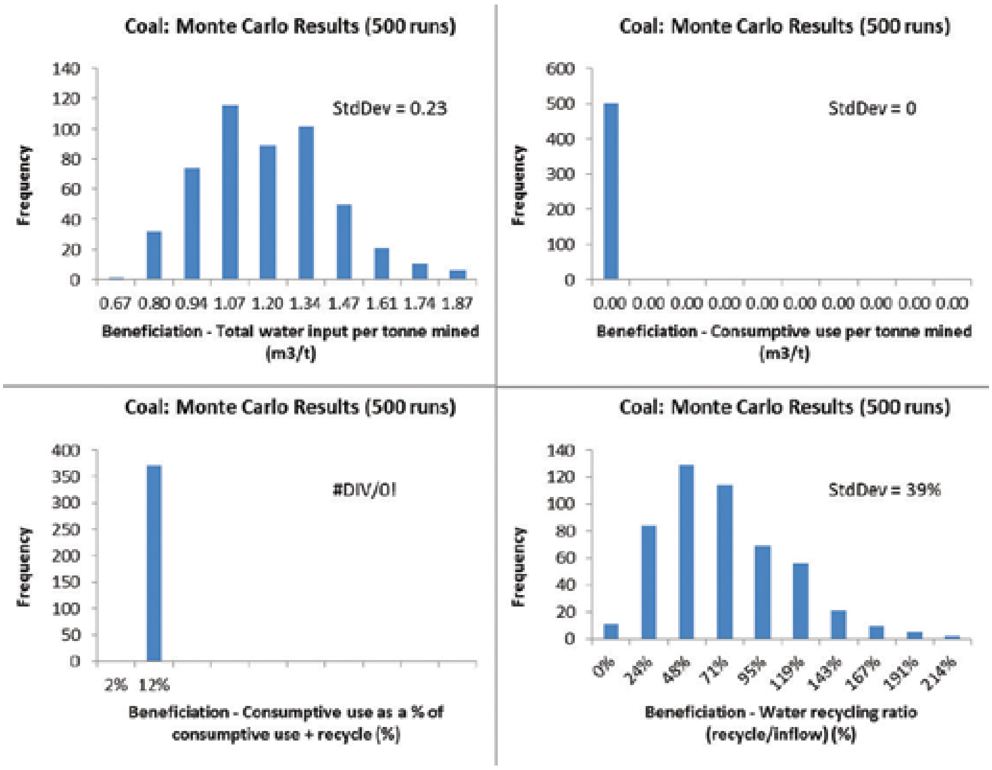

Figure C12: Effect of variations on beneficiation water balance key indicators

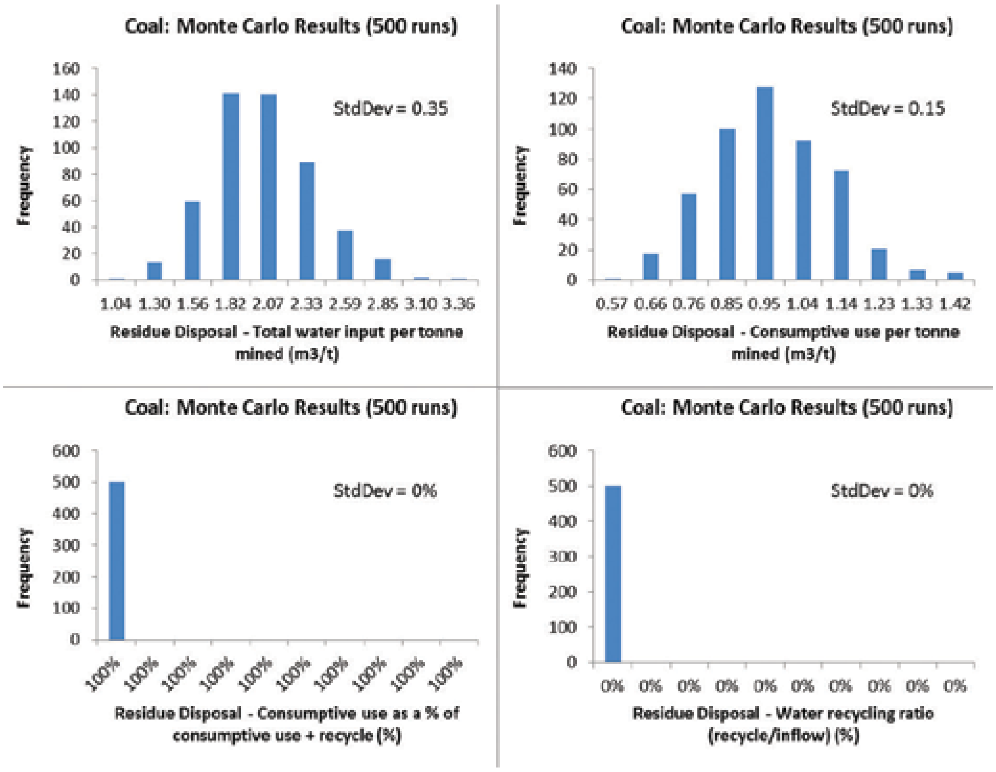

Figure C13: Effect of variations on residue disposal water balance key indicators

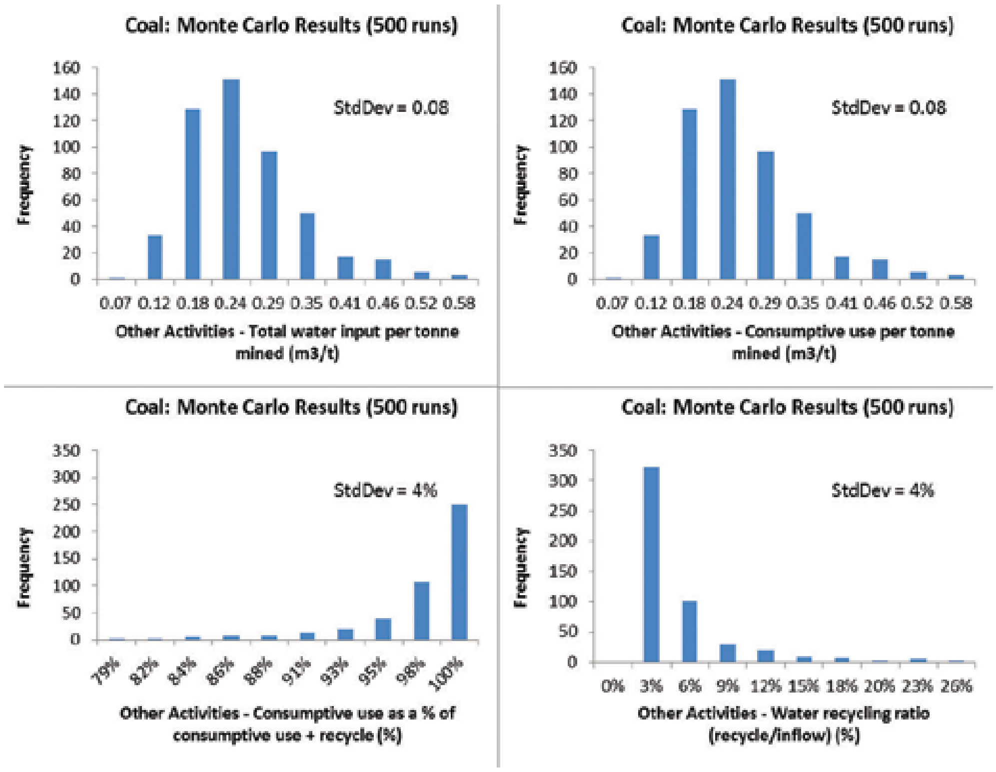

Figure C14: Effect of variations on other use water balance key indicators

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.

APPENDIX D
DETAILED BENCHMARK VALUES

D1 Introduction

This Appendix provides the detailed benchmark values for the 4 different commodity groupings as shown in Tables 4 to 12 in the main report but with the data included for the water balance subsections of mining, beneficiation and residue disposal. It should be emphasised that the water balance data density for these sub-section water balances was generally poor and that the reliability of the data for the sub-sections is therefore also low. The data for the sub-sections is therefore not included in the National Benchmark Tables shown in the main report and are shown here for information only.

Table D1: Water use efficiency indicators for coal mines

Coal		All mines			Valid water balances			Top 3 mines		
	Units	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
Total Mine										
Total Mine – Total specific water use per ROM ton	m³/t	0.79	0.08	2.67	1.13	0.20	2.67	0.70	0.20	1.33
Total Mine – Consumptive specific water use per ROM ton	m³/t	0.67	0.05	2.67	0.95	0.20	2.67	0.38	0.20	0.48
Total Mine - % wastewater not recycled	%	63%	11%	100%	63%	11%	100%	72%	15%	100%
Total Mine – Water recycle ratio	%	48%	0%	87%	16%	0%	32%	6%	0%	16%
Mining										
Mining – Total specific water use per ROM ton	m³/t	0.19	0.00	1.08	0.21	0.00	1.08	0.45	0.09	1.08
Mining – Consumptive specific water use per ROM ton	m³/t	0.09	0.00	0.30	0.05	0.00	0.18	0.06	0.00	0.18
Beneficiation										
Beneficiation – Total specific water use per ROM ton	m³/t	0.31	0.00	0.91	0.39	0.00	0.91	0.12	0.00	0.30
Beneficiation – Consumptive specific water use per ROM ton	m³/t	0.31	0.00	0.91	0.39	0.00	0.91	0.12	0.00	0.30
Residue Disposal										
Residue Disposal – Total specific water use per ROM ton	m³/t	0.49	0.00	2.83	0.30	0.00	0.93	0.05	0.00	0.16
Residue Disposal – Consumptive specific water use per ROM ton	m³/t	0.13	0.00	0.40	0.15	0.00	0.40	0.04	0.00	0.12

Table D2: Water use efficiency indicators for gold mines

Gold		All mines			Valid water balances			Top 3 mines		
	Units	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
Total Mine										
Total Mine – Total specific water use per ROM ton	m³/t	2.46	0.98	6.23	2.67	0.99	6.23	2.09	1.09	3.47
Total Mine – Consumptive specific water use per ROM ton	m³/t	2.41	0.80	6.23	2.64	0.99	6.23	2.02	1.09	3.47
Total Mine - % waste water not recycled	%	75%	33%	100%	78%	33%	100%	60%	33%	100%
Total Mine – Water recycle ratio	%	39%	9%	74%	40%	9%	74%	18%	9%	25%
Mining										
Mining – Total specific water use per ROM ton	m³/t	1.85	0.22	4.89	1.96	0.22	4.89	1.90	0.22	4.89
Mining – Consumptive specific water use per ROM ton	m³/t	1.26	0.00	3.34	1.28	0.00	3.34	0.44	0.00	1.10
Beneficiation										
Beneficiation – Total specific water use per ROM ton	m³/t	1.94	0.00	7.44	2.08	0.00	7.44	1.78	1.39	2.21
Beneficiation – Consumptive specific water use per ROM ton	m³/t	1.90	0.00	7.44	2.03	0.00	7.44	1.66	1.38	2.21
Residue Disposal										
Residue Disposal – Total specific water use per ROM ton	m³/t	1.73	0.00	5.83	1.80	0.00	5.83	1.84	1.28	2.76
Residue Disposal – Consumptive specific water use per ROM ton	m³/t	1.42	0.00	4.99	1.49	0.00	4.99	1.53	1.28	1.83

Table D3: Water use efficiency indicators for platinum mines

Platinum		All mines			Valid water balances			Top 3 mines		
	Units	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
Total Mine										
Total Mine – Total specific water use per ROM ton	m³/t	1.68	1.05	2.63	1.68	1.05	2.63	1.85	1.75	1.94
Total Mine – Consumptive specific water use per ROM ton	m³/t	1.66	1.05	2.63	1.66	1.05	2.63	1.82	1.75	1.86

Other		All mines			Valid water balances			Top 3 mines		
Beneficiation										
Beneficiation – Total specific water use per ROM ton	m³/t	1.19	0.00	3.59	1.33	0.09	3.59	1.12	0.09	2.23
Beneficiation – Consumptive specific water use per ROM ton	m³/t	1.00	0.00	3.59	1.31	0.09	3.59	1.09	0.09	2.23
Residue Disposal										
Residue Disposal – Total specific water use per ROM ton	m³/t	2.55	0.00	21.12	4.19	0.18	21.12	2.23	0.18	3.80
Residue Disposal - Consumptive specific water use per ROM ton	m³/t	2.10	0.00	21.12	3.47	0.04	21.12	0.88	0.10	1.69

Table D5: Standard deviation of water use efficiency indicators per commodity

Standard Deviation	Unit	Coal	Gold	Platinum	Other
Total Mine					
Total Mine - Total specific water use per ROM ton	m³/t	0.19	0.49	0.22	0.20
Total Mine - Consumptive specific water use per ROM ton	m³/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	m³/t	0.22	0.40	0.11	0.11
Mining - Consumptive specific water use per ROM ton	m³/t	0.02	0.47	0.10	0.05
Beneficiation					
Beneficiation - Total specific water use per ROM ton	m³/t	0.23	0.28	0.27	0.27
Beneficiation - Consumptive specific water use per ROM ton	m³/t	0.00	0.00	0.00	0.00
Residue Disposal					
Residue Disposal - Total specific water use per ROM ton	m³/t	0.35	0.37	0.33	0.34
Residue Disposal - Consumptive specific water use per ROM ton	m³/t	0.15	0.19	0.19	0.19
Other Activities					
Other Activities - Total specific water use per ROM ton	m³/t	0.08	0.05	0.06	0.08
Other Activities - Consumptive specific water use per ROM ton	m³/t	0.08	0.05	0.06	0.08

Other		All mines			Valid water balances			Top 3 mines		
Beneficiation										
Beneficiation – Total specific water use per ROM ton	m³/t	1.19	0.00	3.59	1.33	0.09	3.59	1.12	0.09	2.23
Beneficiation – Consumptive specific water use per ROM ton	m³/t	1.00	0.00	3.59	1.31	0.09	3.59	1.09	0.09	2.23
Residue Disposal										
Residue Disposal – Total specific water use per ROM ton	m³/t	2.55	0.00	21.12	4.19	0.18	21.12	2.23	0.18	3.80
Residue Disposal - Consumptive specific water use per ROM ton	m³/t	2.10	0.00	21.12	3.47	0.04	21.12	0.88	0.10	1.69

Table D5: Standard deviation of water use efficiency indicators per commodity

Standard Deviation	Unit	Coal	Gold	Platinum	Other
Total Mine					
Total Mine - Total specific water use per ROM ton	m³/t	0.19	0.49	0.22	0.20
Total Mine - Consumptive specific water use per ROM ton	m³/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	m³/t	0.22	0.40	0.11	0.11
Mining - Consumptive specific water use per ROM ton	m³/t	0.02	0.47	0.10	0.05
Beneficiation					
Beneficiation - Total specific water use per ROM ton	m³/t	0.23	0.28	0.27	0.27
Beneficiation - Consumptive specific water use per ROM ton	m³/t	0.00	0.00	0.00	0.00
Residue Disposal					
Residue Disposal - Total specific water use per ROM ton	m³/t	0.35	0.37	0.33	0.34
Residue Disposal - Consumptive specific water use per ROM ton	m³/t	0.15	0.19	0.19	0.19
Other Activities					
Other Activities - Total specific water use per ROM ton	m³/t	0.08	0.05	0.06	0.08
Other Activities - Consumptive specific water use per ROM ton	m³/t	0.08	0.05	0.06	0.08

Table D6: National water use efficiency benchmarks and ranges for coal mines

Coal Mines	Units	Benchmark	Min (1x$\sigma\sigma$)	Max (1x$\sigma\sigma$)
Total Mine				
Total Mine - Total specific water use per ROM ton	m^3/t	0.70	0.50	0.89
Total Mine - Consumptive specific water use per ROM ton	m^3/t	0.38	0.20	0.55
Total Mine - % waste water not recycled	%	72%	60%	84%
Total Mine - Water recycle ratio	%	6%	0%	38%
Mining				
Mining - Total specific water use per ROM ton	m^3/t	0.45	0.23	0.67
Mining - Consumptive specific water use per ROM ton	m^3/t	0.06	0.04	0.09
Beneficiation				
Beneficiation - Total specific water use per ROM ton	m^3/t	0.12	0.00	0.35
Beneficiation - Consumptive specific water use per ROM ton	m^3/t	0.12	0.12	0.12
Residue Disposal				
Residue Disposal - Total specific water use per ROM ton	m^3/t	0.05	0.00	0.40
Residue Disposal - Consumptive specific water use per ROM ton	m^3/t	0.04	0.00	0.19

Table D7: National water use efficiency benchmarks and ranges for gold mines

Gold Mines	Units	Benchmark	Min (1x$\sigma\sigma$)	Max (1x$\sigma\sigma$)
Total Mine				
Total Mine - Total specific water use per ROM ton	m^3/t	2.09	1.60	2.57
Total Mine - Consumptive specific water use per ROM ton	m^3/t	2.02	1.52	2.51
Total Mine - % waste water not recycled	%	60%	47%	73%
Total Mine - Water recycle ratio	%	18%	0%	50%
Mining				
Mining - Total specific water use per ROM ton	m^3/t	1.90	1.50	2.30
Mining - Consumptive specific water use per ROM ton	m^3/t	0.44	0.00	0.91
Beneficiation				
Beneficiation - Total specific water use per ROM ton	m^3/t	1.78	1.50	2.06
Beneficiation - Consumptive specific water use per ROM ton	m^3/t	1.66	1.66	1.66

Gold Mines	Units	Benchmark	Min (1x$\sigma\sigma$)	Max (1x$\sigma\sigma$)
Residue Disposal				
Residue Disposal - Total specific water use per ROM ton	m³/t	1.84	1.47	2.21
Residue Disposal - Consumptive specific water use per ROM ton	m³/t	1.53	1.34	1.72

Table D8: National water use efficiency benchmarks and ranges for platinum mines

Platinum Mines	Units	Benchmark	Min (1x$\sigma\sigma$)	Max (1x$\sigma\sigma$)
Total Mine				
Total Mine - Total specific water use per ROM ton	m³/t	1.85	1.64	2.07
Total Mine - Consumptive specific water use per ROM ton	m³/t	1.82	1.60	2.04
Total Mine - % waste water not recycled	%	65%	42%	78%
Total Mine - Water recycle ratio	%	39%	2%	76%
Mining				
Mining - Total specific water use per ROM ton	m³/t	1.22	1.12	1.33
Mining - Consumptive specific water use per ROM ton	m³/t	0.46	0.36	0.56
Beneficiation				
Beneficiation - Total specific water use per ROM ton	m³/t	1.46	1.19	1.74
Beneficiation - Consumptive specific water use per ROM ton	m³/t	1.46	1.46	1.46
Residue Disposal				
Residue Disposal - Total specific water use per ROM ton	m³/t	1.92	1.59	2.25
Residue Disposal - Consumptive specific water use per ROM ton	m³/t	1.08	0.89	1.28

Table D9: National water use efficiency benchmarks and ranges for other mines

Other Mines	Units	Benchmark	Min (1x)	Max (1x)
Total Mine				
Total Mine - Total specific water use per ROM ton	m3/t	0.96	0.76	1.16
Total Mine - Consumptive specific water use per ROM ton	m3/t	0.65	0.45	0.86
Total Mine - % waste water not recycled	%	52%	39%	65%
Total Mine - Water recycle ratio	%	45%	10%	80%
Mining				
Mining - Total specific water use per ROM ton	m3/t	0.19	0.07	0.30
Mining - Consumptive specific water use per ROM ton	m3/t	0.02	0.00	0.06
Beneficiation				
Beneficiation - Total specific water use per ROM ton	m3/t	1.12	0.85	1.40
Beneficiation - Consumptive specific water use per ROM ton	m3/t	1.09	1.09	1.09
Residue Disposal				
Residue Disposal - Total specific water use per ROM ton	m3/t	2.23	1.90	2.57
Residue Disposal - Consumptive specific water use per ROM ton	m3/t	0.88	0.68	1.07

NOTES

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