

OPTIMUM COAL MINE WATER RECLAMATION PROJECT

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ABSTRACT

Optimum Coal Mine comprises numerous defunct, active and future mining sections. The mine is primarily a large opencast coal mine. Opencast and underground mining activities have a significant impact on surface and groundwater resources. To ensure that the mine will be able to continue with their mining operation in the catchment, the extent of this impact requires that substantial intervention and mitigation measures are implemented to ensure the environmental integrity and economic use of the catchments' water resources.

Developing a long-term mine water management strategy, numerous scenarios had to be analysed. The various scenarios are a combination of numerous water management activities. The main components of the mines' integrated water management strategy include:

- Management of water recharge by rehabilitation of disturbed land;
- Beneficial reuse of impacted mine water for coal plant process water, irrigation, mining operations and
- Reclamation and desalination of remaining excess impacted mine water to potable standard.

From the mine's water balance, it is evident that the continued implementation of numerous water management actions is required to mitigate the water resources impact in a sustainable manner. In addition the installation of a water reclamation plant at Optimum Coal Mine (15Mℓ/day) is a key step for the mine to achieve a zero impact target.

1. BACKGROUND

Optimum Coal Mine is a multi-product mine with a contract to supply Hendrina Power Station with coal until 2018. Optimum Coal Mine also exports a significant quantity of coal. Optimum Coal Mine lies in the upper reaches of the Middelburg Dam Catchment. The dam has a maximum water-holding capacity of 48 Mm³. It receives run-off from the Klein Olifants Catchment with a total drainage area of 1 550 km². Run-off from this catchment is in the order of 5.5% of the average annual rainfall, coming to a total of some 60 Mm³/a. The mean annual rainfall for Optimum Coal Mine based on a 80-year rainfall record is 687 mm, while the annual potential evaporation for the area is estimated at roughly 1,700 mm.

The mine lease area for Optimum Coal Mine is 383 km². The average annual run-off prior to mining from the mine lease area was 14.7 Mm³/a, which constitutes about 25% of the natural catchment run-off. The Mine clearly plays a dominant role in modifying the natural hydrology and runoff to Middelburg Dam. To date, the mine has disturbed roughly 6,870 Ha of land and plans to disturb an additional 3,136 Ha over the remaining life of the mine. Furthermore, the mine has mined 1,532 Ha via underground board and pillar mining and plans to mine an additional 2,687 Ha via board and pillar mining. Figure 1 depicts the mine's locality within the Klein Olifants River Catchment, as well as the layout of the relevant mining areas.

The respective opencast and underground mining activities have a significant impact on surface and groundwater resources. To ensure that the mine will be able to continue with their mining operation in the catchment, the extent of this impact requires that substantial intervention measures are implemented to ensure the environmental integrity and economic use of the catchments' water resources.

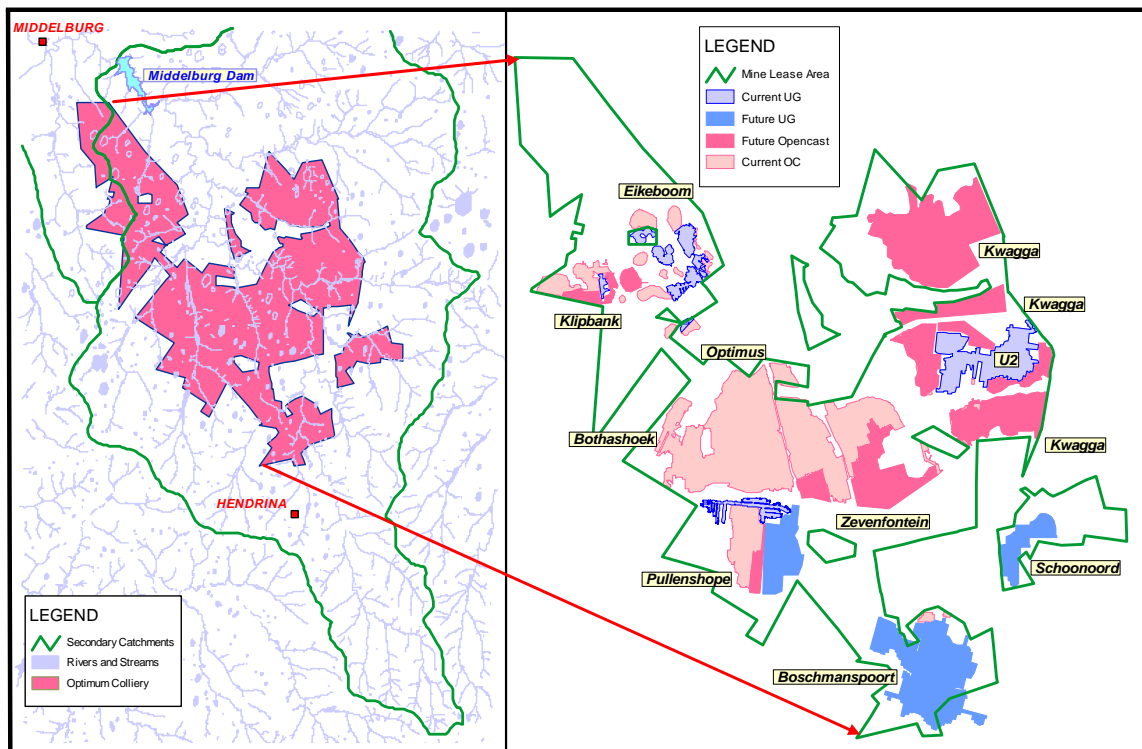


Figure 1. Catchment locality and mine layout

2. HISTORY OF MINING ACTIVITIES

Mining activities at Optimum Coal Mine commenced during the 1970's as an underground bord and pillar mine in the Pullenshope area. During 1971 the mine initiated an opencast strip mine, with mining activities commencing in the Optimus mining area. At that stage, very little legislation existed that could guide the opencast mining activities towards environmentally responsible mining. Strip mining activities started within the Woestalleen East Spruit and proceeded in an easterly and westerly direction. No stream diversion was legally required at that time to mine through a stream. Figure 2 represents a closer view of the earlier mining activities at Optimum Coal Mine. In addition to this the stripping of topsoil prior to mining an area was also not required, which implied that the rehabilitation of the opencast mining areas received little attention.

Mining within the Woestalleen East Spruit also resulted in voids that were left open and these features formed the Lapa Dam, which is currently one of the mines affected water storage facilities. During the late eighties to early nineties, significant changes to the relevant legislation were made requiring mining companies to take cognisance of environmental issues during mining and address all identified impacts in an environmental management programme (EMP). This document received input from all regulators, to ensure impacts were managed on a continuous basis in line with regulatory requirements.

During the early days of Optimum Coal Mine little was done in terms of appropriate water management, which meant the separation of clean and affected water, as well as the re-use of affected water, was not a high priority and led to continuous spills and discharges into the aquatic environment. In 1993, the mine needed to develop the Pullenshope mining area. In order to do this, the mine had to implement numerous water management controls (including flood prevention measures), which included the Pullenshope stream diversion, before mining could commence. Figure 3 depicts the extent of this diversion, which is still functional and upgraded on an annual basis as mining progresses in the area.



Figure 2. Optimus mining area

In summary, legislation since 1991 required mines to do detailed environmental impact assessments and have approved EMP's before mining can commence. This applies to the extension of existing operations and new areas as well. In addition to this, the Department of Water and Environmental Affairs (DWEA) is currently implementing a Waste Discharge Charge System (WDCS) to promote waste reduction and conservation. It forms part of the Pricing Strategy, which was established under the National Water Act (NWA). The Pricing Strategy articulates the aims of the Waste Discharge Charge System:

- Promote the sustainable development and efficient use of water resources.
- Promote the internalization of environmental costs by impactors.
- Recover some of the costs of managing water quality.
- Create financial incentives for dischargers to reduce waste and use water resources in a more optimal way.

The upper Olifants catchment, including the Klein Olifants River catchment, is one of three priority areas, targeted for implementation of the WDCS, by DWEA.

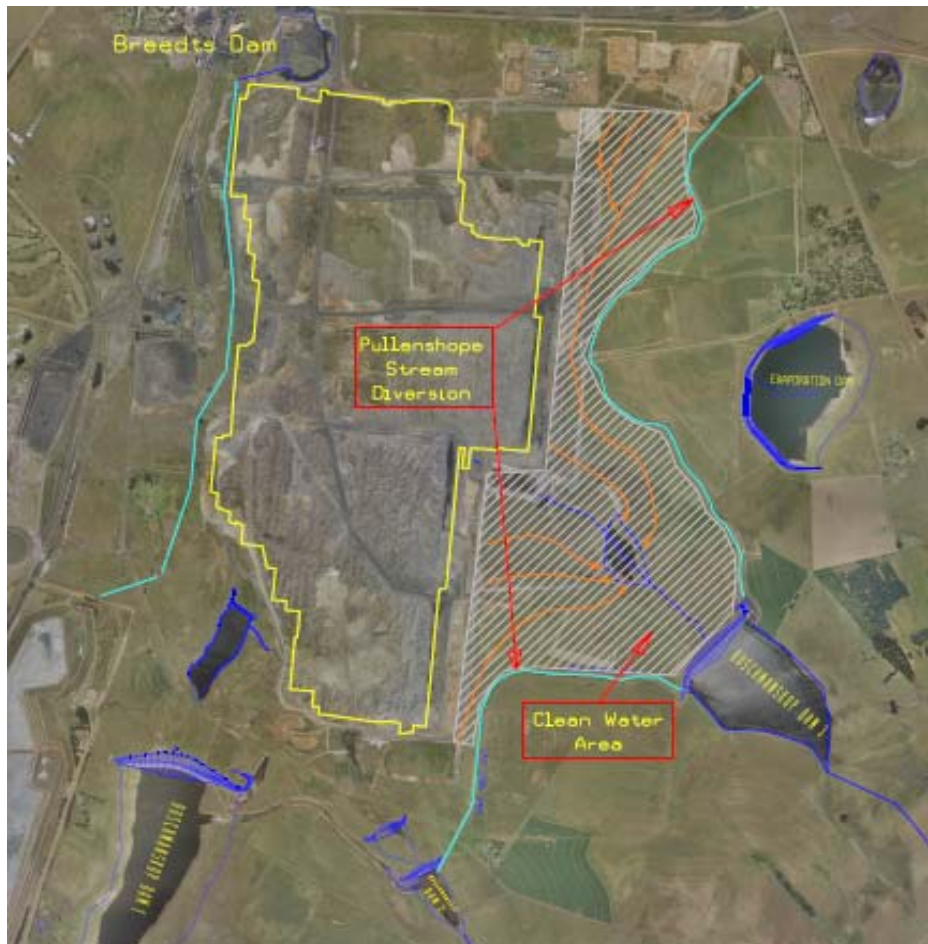


Figure 3. Pullenshope mining area and stream diversion

3. WATER MANAGEMENT PRINCIPLES

The development of a water management strategy requires consideration of the DWEA's hierarchy of water management controls. This hierarchy of controls formed the basis of implementing water management on the mine. This approach is considered best practice, and in terms of water management cost, it makes sound financial sense.

The priorities in terms of this hierarchy are:

- Keeping clean water clean. This applies to both water upstream of mining, as well as water from rehabilitated areas.
- Containing impacted water with low risk of spilling.
- Maximised reuse of impacted water within the mining environment.
- Treatment of water to render it fit for use, where it cannot be reused without treatment.
- Release of water in terms of a Water Use Licence where permitted by the authorities.

Managing the affected water make within a closed water circuit generally requires the following to be achieved:

- The average water make for average rainfall should be balanced by either the average water usage, or else storage is required for the surplus water make;
- Storage is required to balance the wet and dry seasons;
- If the probability of spilling impacted water is to be 2% or less in any one year, additional storage may still be required to accommodate the very wet periods when there will certainly be an excess of water and dewatering is required to facilitate mining;
- The overall impacted water make must be managed and minimised;
- Maximise the reuse of impacted water for mining purposes;
- Minimise the current use of clean water by the mine;

These water management principles informed and directed the development of a water management strategy.

4. WATER MANAGEMENT STRATEGY

Water management on large opencast mines is intrinsically associated with the hydrological cycle. The hydrology and

geohydrology are both components of the larger hydrological cycle, and can never be viewed in isolation. To manage water in an optimal manner on any mine, a clear understanding of all the components in the hydrological cycle is required. Rainfall recharge rates into the mining area where determined by Hodgson (2006) and are listed in Table 1.

Based on the above, estimates of the expected current and future impacted water volumes were calculated and are reflected in Table 2. To manage the current and future affected water make the mine evaluated various options to reduce the overall water make. In addition to the water make it is also important to note that significant portions of the mined-out opencast portions have accumulated large volumes of water. This water make is governed by the rainfall recharge rates listed in Table 1. The rates are based on a 30- year history of opencast groundwater models within the Witbank Coalfield.

Table 1. Opencast rainfall recharge rates (after Hodgson, 2006)

Sources which contribute water	Water sources into open pits	Suggested average values
Rain onto ramps and voids	20 to 100 % of rainfall	70 % of rainfall
Rain onto unrehabilitated spoils	30 to 80 % of rainfall	60 % of rainfall
Rain onto levelled spoils (run-off)	3 to 7 % of rainfall	5 % of rainfall
Rain onto levelled spoils (seepage)	15 to 30 % of rainfall	20 % of rainfall
Rain onto rehabilitated spoils (run-off)	5 to 15 % of rainfall	10 % of rainfall
Rain onto rehabilitated spoils (seepage)	5 to 10 % of rainfall	8 % of rainfall
Surface run-off from surrounding areas into pits	5 to 15 % of total pit water	6 % of total pit water
Groundwater seepage	2 to 15 % of total pit water	10 % of total pit water

Figure 4 depicts current and future mined-out areas and associated volumes of water stored within them. Thus from a long-term water management point of view it is crucial to take cognisance of this when sustainable management options are implemented.

Figure 5 summarises Optimum’s detail water balance and includes the optimised reuse of affected water by the mining operation. From the mine’s water balance, it is evident that the continued implementation of numerous water management actions are required to mitigate the catchment water resources impact in a sustainable manner. It is also clear that the accumulation of water has now reached a situation where $\pm 15\text{MI/day}$ of excess affected water is generated that needs to be managed on a daily basis. Please note that the respective water uses on the graph are depicted by the red bars, whereas the green bars reflect additional water makes.

Table 2. Estimated decant volumes for the whole Optimum Coal Mine complex (Hodgson 2006)

Mining Section	Current	Long-Term
	Expected Decant Volume (m ³ /d)	Expected Decant Volume (m ³ /day)
Eikeboom	1,573	1,572
Klipbank	1,148	1,667
Optimus	8,095	8,095
Pullenshope	2,123	2,232
Zevenfontein	10,118	8,334
Kwagga	2,000	12,375
Arnot U2	517	422
Boschmanspoort	100	326
Schoonoord	0	76
Totals	25,674	35,099

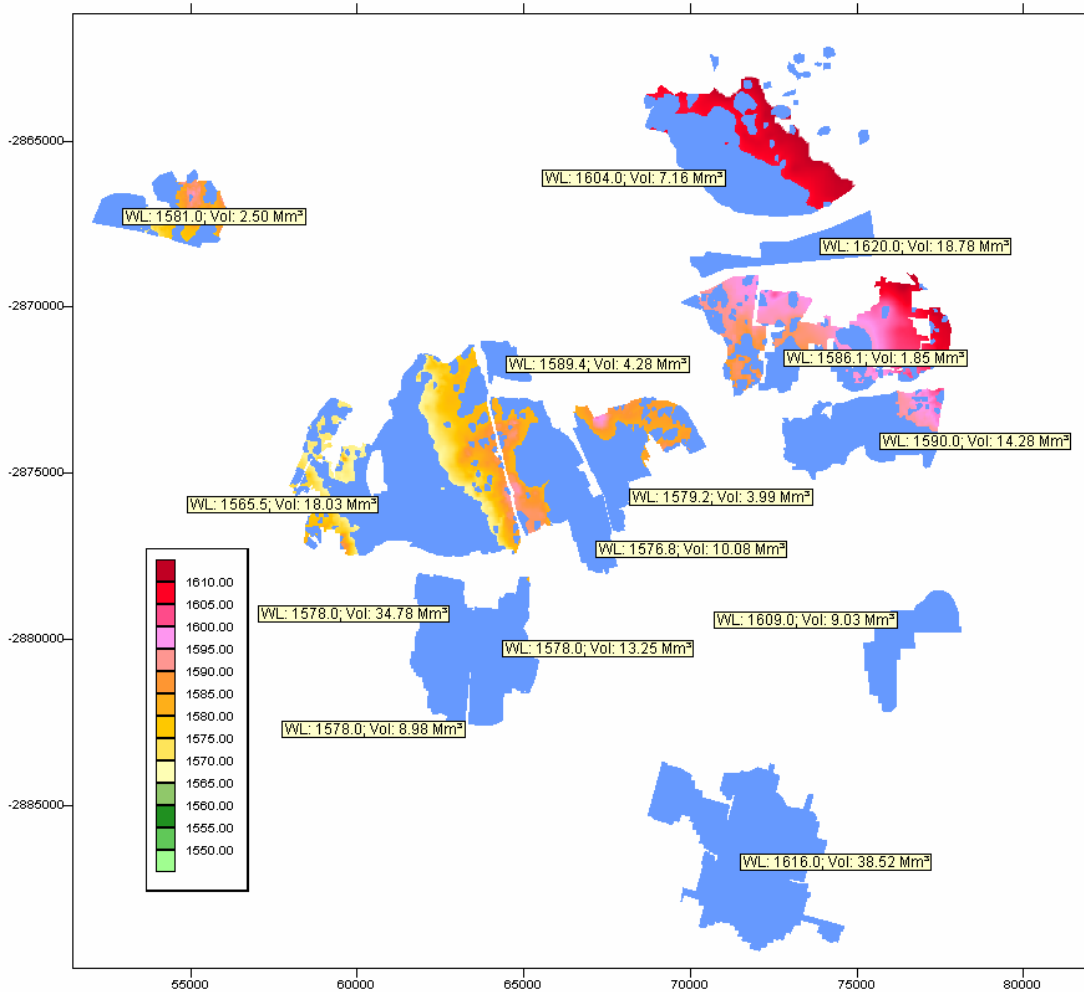


Figure 4. Water stored within the mined-out opencast workings (Hodgson, 2006)

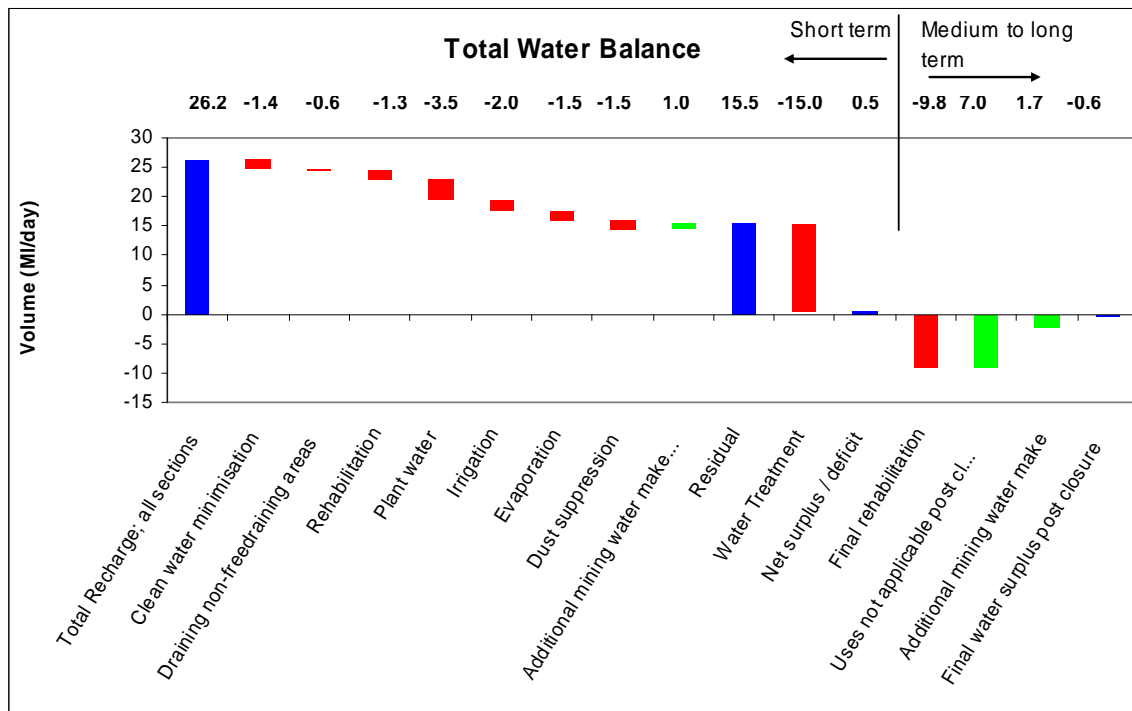


Figure 5. Optimum Coal Mine water balance, excluding the Kwagga and Eikeboom Sections

As such, the water management strategy will thus be a dynamic and ongoing process that involves risk assessment and quantification, and adaptation of plans to meet changing circumstances. Bearing this in mind, the long-term water management strategy should enable the mine to manage the overall water balance in a sustainable way, to ensure legal

compliance and to suit the requirements at mine closure.

In developing a long-term strategy, numerous scenarios had to be analysed. The various scenarios were a combination of several water management activities, which were categorised into two major groupings, namely:

- Management alternatives and;
- Mine water reclamation scheme

Combinations of activities within these groupings were evaluated and rated to satisfy the problem statement. A summary of the process is depicted in Figure 6.

Six scenarios were investigated, evaluating various combinations of water control activities, which included the “Do Nothing Case”. Five scenarios excluding the “Do Nothing Case” included actions such as:

- Reduce water make and minimise the cost of the WTP by accelerating the mine rehabilitation;
- Reduce water make and minimise the cost of WTP by implementing other low cost water management measures such as reuse, irrigation and dust suppression;
- A combination of the above two bullets;
- Treat all excess water from all the sections without implementing any other water management measure;
- Keep WTP small and ensure that Life of Mine provides gradual water storage for Kwagga;

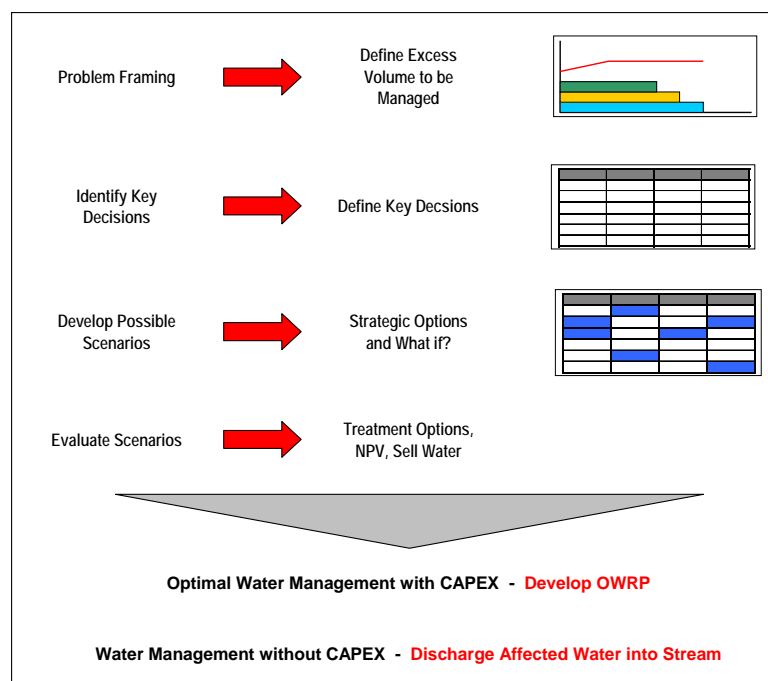


Figure 6. Scenario analysis process

The recommended go forward scenario is based on a combination of the first two bullets, i.e. accelerating the rehabilitation of mined- areas, optimising clean and dirty water separation systems, optimising the reuse of affected water for the mining operation and treating the remaining excess affected water. The “Do Nothing Case” is not feasible, as it threatens the mine’s license to operate and will certainly lead to prosecution by the regulator.

Treatment of excess impacted mine water was therefore a key component of integrated future mine water management.

5. WATER TREATMENT OF SURPLUS AFFECTED WATER

The key components of the Optimum Water Reclamation Project (OWRP) include raw water collection, treatment, treated water storage and distribution, sludge and brine disposal, and bulk support services, as shown in Figure 8.

With the implementation of the OWRP two alternatives were evaluated with respect to the implementation of the sustainable long-term management control of such a facility.

- Option 1 – Fit for purpose simple solution to mitigate excess affected water, (i.e. treat water and discharge directly into receiving water body).
- Option 2 – Value add opportunity to recover some of the operational costs, (i.e. stabilise and disinfect treated water and supply to the Local Municipality, to generate revenue).

The different components of the optimum water reclamation project are briefly described

Mine Water Collection

The mine water evaporation dam is the central depository of impacted water on the Optimum Mine complex. All excess impacted water, not utilised by mining operations and coal washing is diverted to the evaporation dam. It provides a large storage capacity to even out the short-term and seasonal variation in excess mine water production.

The mine water is gravity drained from the evaporation dam to the mine water reclamation plant.

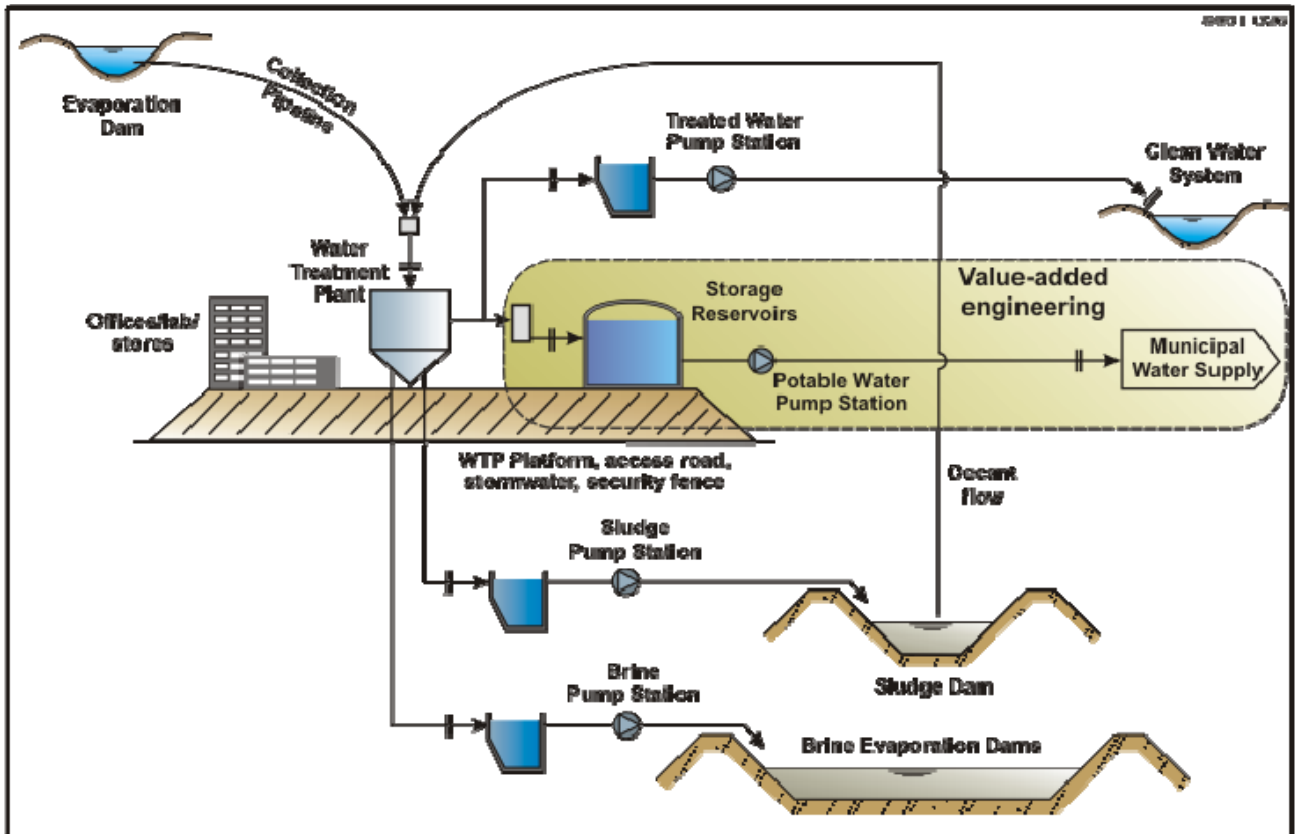


Figure 8. Optimum Water Reclamation Project - Schematic Diagram Showing the Raw Water Collection, Treatment, Storage, Distribution, and Sludge and Brine Disposal (Golder, 2008)

The impacted mine water is near neutral, contains mainly calcium magnesium sulphate salts with a relatively low metals content. It therefore represents a brackish water which is relatively easy to treat and reclaim. The representative mine water quality is reflected in Table 3.

Mine Water Treatment

The mine water treatment technology is based on Keyplan's high recovery desalination technology. The key components of the mainstream treatment process include the following;

- pre treatment for solids and metals removal
- filtration using selective granular media for manganese polishing
- ultra filtration for suspended and colloidal solids removal
- RO/NF membrane treatment for desalination.

The integrated mine water treatment process is shown on Figure 9. The overall treatment process is aimed at maximising water recovery and minimising waste production. The target water recovery is more than 98%. This is the second application of this membrane based treatment technology, the first such project being the eMalahleni Water Reclamation Project.

Table 3. Design Mine Water Quality

Water Quality Parameter	Unit	Evaporation Dam Water	
		50 percentile	95 percentile
Inorganic quality:			
pH	-	7.0	8.5
Conductivity	mS/m	525	635
TDS	mg/ℓ	5220	6300
Sodium, Na	mg/ℓ	110	140
Potassium, K	mg/ℓ	50	85
Calcium, Ca	mg/ℓ	550	595
Magnesium, Mg	mg/ℓ	570	750
Chloride, Cl	mg/ℓ	35	45
Sulphate, SO ₄	mg/ℓ	3500	4400
M Alkalinity, CaCO ₃	mg/ℓ	340	465
Fluoride, F	mg/ℓ	0.5	0.8
Nitrate, NO ₃ -N	mg/ℓ	0.2	1.2
Ammonia, NH ₃ -N	mg/ℓ	0.4	1.7
Metals:			
Iron, Fe	mg/ℓ	0.01	0.6
Aluminium, Al	mg/ℓ	0.02	0.5
Manganese, Mn	mg/ℓ	0.2	2.5
Trace elements:			
Barium	mg/ℓ	0.02	0.03
Silica, SiO ₂	mg/ℓ	2.3	5.8
Strontium	mg/ℓ	N/A	N/A
Organic:			
Suspended Solids	mg/ℓ	56	150
TOC	mg/ℓ	11	30
Chlorophyll	µg/ℓ	9	30

Water Polishing and Distribution

The desalinated water targeted for potable use is further polished by stabilisation (using limestone) and disinfection (using chlorine). This good quality water is pumped to surrounding communities, with the excess water discharged to the clean water diversion canal upstream of the Pullenshope mine workings.

A fraction of the treated water is released to a tributary of the Klein Olifants River to support the environmental water requirements, as established by the Department's aquatic eco-system reserve determination.

Waste Generation and Disposal

The mine water treatment process produces two waste streams;

- A sludge stream containing mainly calcium and magnesium salts with limited metal content, since the feed mine water is not acidic and does not carry a high metals load.
- A brine stream containing high soluble salts, mainly sodium and some magnesium salts.

The sludge is disposed to a sludge lagoon for interim storage, until the co-disposal with mining wastes can be authorised and by-products recovery can commence.

The small brine stream is disposed to a lined evaporation dam, constructed to satisfy and comply with all the relevant legal requirements for hazardous waste disposal sites.

The integrated project represents the state of the art in terms of mine water desalination and will produce high-quality product water, complying with all the requirements of the DWAE Guidelines for Drinking Water Use, 1996.

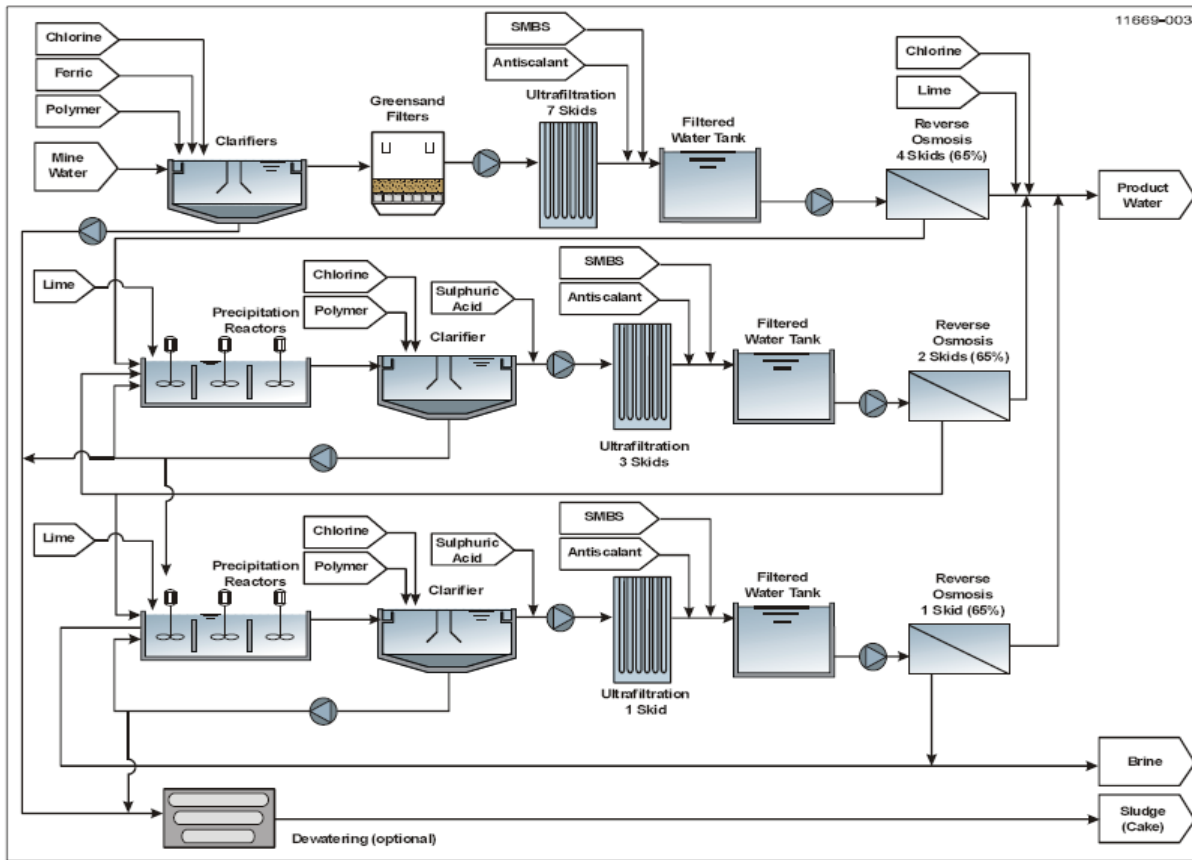


Figure 9. Integrated mine water treatment process (Keyplan, 2008)

6. POTENTIAL WATER SUPPLY MARKET.

The water resources of the Upper Olifants River Catchment are over utilised and under stress, with the local municipalities and power generation industry relying heavily on inter-basin water transfer schemes, (i.e. from the Komati, Usutu and Vaal catchments). Mining activities in the catchment have the ability to generate large volumes of affected water, which could be re-used by the above sectors to reduce the reliance on inter-basin transfers.

It is also important to note that future mining projects in the region will have difficulty receiving water allocations from the DWEA, due to the current deficit of water in the entire catchment. Based on this, the OWRP does also have the potential to supply future mining projects in the region with treated water.

During 2006 a Memorandum of Understanding (MoU) between Optimum Coal Holdings (OCH) and the Local Municipality gave a non-binding commitment to make treated water available from the water reclamation project. On the basis of the MoU, the Local Municipality did not pursue any alternative water supply options for the surrounding communities. An expectation was therefore created that the OWRP would be the future preferred water supply to the local communities.

The DWEA is aware of the critical water supply situation to the surrounding communities. The Department has compiled a water resources management strategy for the Upper Olifants River Catchment that incorporates the use of reclaimed mine water. This strategy therefore includes the Optimum reclaimed mine water as the preferred supplier of water to the surrounding communities. In addition to the above, the DWEA is unlikely to issue a water use license for a water reclamation project that does not include a municipal water supply component. The department is certainly considering the beneficial use of the available water resources in the approval and granting of water use licenses. Bearing this in mind it is therefore important that the OWRP considers the supply of treated water to the Local Municipality, in their long-term water management strategy.

7. CONCLUSIONS

To conclude, Optimum's long-term water management strategy is based on the following approach:

- Minimization of the production of impacted water by responsible mining and land use practices
- Collection and use of impacted water on the mine complex to satisfy the entire Mine's own needs. The objective is to have the Mine independent of imported water sources.
- Excess impacted mine water; still remaining will be treated to a standard fit for discharge or use by the surrounding communities.
- The excess reclaimed water will be managed as a resource and the Mine will position as a local and regional water supplier.
- The water resource will continue to be available in the post mining era to the local and regional water users. It is therefore important to develop a diverse base of reclaimed water users, including water users which will continue to exist post mining.

It is also important to note that in terms of water management, there are various uncertainties that need to be managed on an ongoing basis:

- Variables that cannot be controlled such as future rainfall events, possibly global warming effects;
- Technical uncertainties such as the actual recharge through rehabilitated spoils (as opposed to the predicted recharge);
- The long term value of potable water;
- Mining related uncertainties such as the mine plan, strategies around water management and the possible use of storage available in mined out areas.

As such, the water management strategy will thus be a dynamic and ongoing process that involves risk assessment and quantification, and adaptation of strategies to meet changing circumstances. To ensure this is done on a continuous basis, the mine has compiled an integrated water management plan that is updated on annual basis.

8. REFERENCES

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