PAPER 7

Re-watering of West Rand Dolomitic Compartments: Implications for JB Marks Local Municipality

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ABSTRACT

The Far West Rand goldfield represents one of the richest gold mining areas in the world overlain by one of the largest dolomitic aquifers in the world. This posed unique challenges to underground mining development as well as the surface municipal development. During the peak of gold mining in the Far West Rand a decision was made to reduce the large influx of dolomitic groundwater into the underlying mine void by dewatering the >1.2 km thick dolomitic compartments. By dewatering the dolomitic compartments significant sinkhole formation and widespread ground instability was initiated, a situation which still poses challenges for development in this area. Mining is not a sustainable practice, and many gold mines are closing down operations. Mining adversely affects not only water quality but also quantity, posing a significant risk to water resources in the Mooi River catchment.

Although various scenarios predicting the post-mine closure consequences have been modeled, the uncertainty remains. However, all modeled scenarios are in agreement on three important aspects: 1) the water quality for downstream users (including JB Marks Local Municipality) will be compromised; 2) the quantity of water reaching the downstream users, during the period after pumping ceases and the time the mine void and overlying dolomitic compartments have naturally filled-up and contribute to the water resource, will be compromised and 3) renewed surface instability due to sinkhole formation and potential re-activation of existing sinkholes will pose a threat to infrastructure, built environment and socio-economic development in the catchment. Unless the complexities of the long-term risks associated with post-mine closure are addressed in a coordinated manner as a matter of urgency through a rational and integrated spatial planning process and strategy formulation the risk of a socio-economic impact in the not-too-distant future is a certainty. Additionally, environmental pollution, dysfunctionality of infrastructure (transport, roads, water, and sanitation) and compromised sustainability of the built environment will impact negatively on economic growth in the region.

1. INTRODUCTION

South Africa is a water scarce country and already utilise 98% of its existing freshwater resources intensively (WWF 2016). Water is considered a key limiting resource for South Africa which may negatively affect social and economic development (Blignaut and van Heerden 2009). The sustainable use and management of water resources is therefore becoming vital. The situation would be further exacerbated by the effects of climate change and hydrological variability and future social and economic pressures (Mukheibir and Sparks 2003). The protection and utilisation of natural resources therefore needs to be managed in an integrated approach to achieve sustainable development as expressed in the Sustainable Development Goals (United Nations Development Program (UNDP) 2020).

Strategic surface water and groundwater source areas (SWSAs) of national importance are those considered worthy of protection because they are the only or primary source of water that sustains society and the associated economic activities in a specific area (Nel et al. 2013; Le Maitre et al. 2018a; Le Maitre et al. 2018b). Fifty-seven groundwater WSAs were identified in South Africa of which the Far West Karst region is relevant to this study (Le Maitre et al. 2018a).

In addition to the scarcity and variability of the available water resources, deterioration in the quality of South Africa's water resources, as a result of both past and current developments in addition to poor enforcement of legislation, place additional strain on safe water provision (DWS 2018). Land and water degradation, together with their subsequent impacts on land and water users, cannot easily be separated or managed independent from one another. Furthermore, catchments are often divided by provincial and other political or administrative boundaries and inter-basin transfers allow water to cross catchment boundaries. Therefore, co-ordinated and integrated planning and implementation are required at all levels, from national government through provincial authorities to individual landowners.

South Africa moved away from the traditional fragmented or supply-oriented water management to Integrated Water Resource Management (IWRM), which is a holistic approach that seeks to integrate the management of the physical environment within the broader socio-economic and political framework (UNESCO 2009, Jonker 2014).

JB Marks Local Municipality was established by the amalgamation of Ventersdorp Local Municipality and Tlokwe City Council Local Municipality on 3 August 2016 (Municipal Demarcation Board (MDB) 2018). The JB Marks Local Municipality relies on both surface- and groundwater as water resources (IDP 2019; Van der Walt et al. 2002, Nealer and Raga 2008a; Nealer and Raga 2008b). The surface water supply is via the Mooi River Catchment (a total area of 1 800 km^2) which includes the Mooi River, Wonderfontein Spruit and Loop Spruit (Figure 1). The Wonderfontein Spruit crosses the provincial boundary between North West and Gauteng Provinces as well as the municipal boundary between JB Marks Local Municipality and Merafong City Local Municipality (MLM) (Van der Walt et al. 2002) (Figure 1). JB Marks Local Municipality is both a water service authority (WSA) and water service provider (WSP) in terms of the NWA (Act no. 39 of 1998) and Water Services Act (WSA) (Act no.108 of 1997. In this regard, the municipality is responsible for ensuring access to water services (governance function) and the provision of water services to consumers, in accordance with the relevant legislation.

1.1. Hydrology

In the Far West Rand karst north–south trending dykes intrusive into the dolomite formed impermeable barriers, effectively forming separate groundwater compartments (Figure 1). Where groundwater reaches the downstream dyke barrier it breaches the surface and create springs (Enslin and Kriel 1959, 1968; Swart et al. 2003a).

Soon after deep level mining in the Far West Rand goldfield (between

Randfontein and Carletonville) started (1960s) underground mining operations were constantly flooded by groundwater from the overlying dolomitic karst aquifer. To protect mining operations, below the karst aquifer from re-circulating and constantly pumping water from the mine void, authorities granted mines permission to partly dewater the dolomitic aquifer (Venterspost, Bank, Oberholzer compartments) in 1960 (Swart et al. 2003a). This involved extracting more water than would naturally recharge the karst aquifer and discharging it outside the boundaries of the compartment, effectively lowering the groundwater table (up to 1 000 m).

Dewatering of the dolomitic compartments however, had an unavoidable consequence of extensive ground instability in the form of sinkholes and dolines and the drying up of high-yielding karst springs and irrigation boreholes (Swart and van Schalkwyk 2001; Swart et al. 2003b; Winde and Stoch 2010; Winde & Erasmus 2011). After the extent of the ground instability due to dewatering became evident in the 1960's Government established committees such as the Far West Rand Dolomitic Water Association (FWRDWA) and the State Co-ordinating Technical Committee (SCTC) to research, monitor and manage the consequences of dewatering (Phogole and Mulaba-Bafubiandi 2013). The majority of cavities that open to surface were never rehabilitated but sinkholes which posed a threat to roads, railway lines and building infrastructure, physical danger to people in highly populated areas or warranted from an aesthetic perspective were backfilled (Swart and van Schalkwyk 2001; Swart et al. 2003; Dill et al. 2007). Materials historically used for backfilling of these cavities include soil, mine waste rock, tailings and cement or a mixture thereof (Dill et al. 2007).

In addition, water of the Lower Wonderfontein Spruit has been diverted into a pipeline (often referred to the 1 m pipeline) from the outflow of Donaldson Dam transporting water for a distance of 32 km over the dewatered dolomitic compartments (Oberholzer, Venterspos, and Bank) (Van der Walt et al. 2002). The pipeline transports water which has been impacted by anthropogenic activities (urban settlements, wastewater treatment works and defunct gold mines) from its origin on the continental divide situated between Randfontein and Krugersdorp and fissure water from operating mines to the discharge point into a cement lined channel near Oberholzer/Carletonville (Swarts et al. 2003). Mine fissure water and water from wastewater treatment works (WWTW) join the Lower Wonderfontein Spruit before the confluence with the Mooi River upstream of the Boskop Dam, the main reservoir for the water supply of some 250 000 residents of JB Marks Local Municipality (Potchefstroom). Several springs occur along the Mooi River upstream of the Boskop Dam

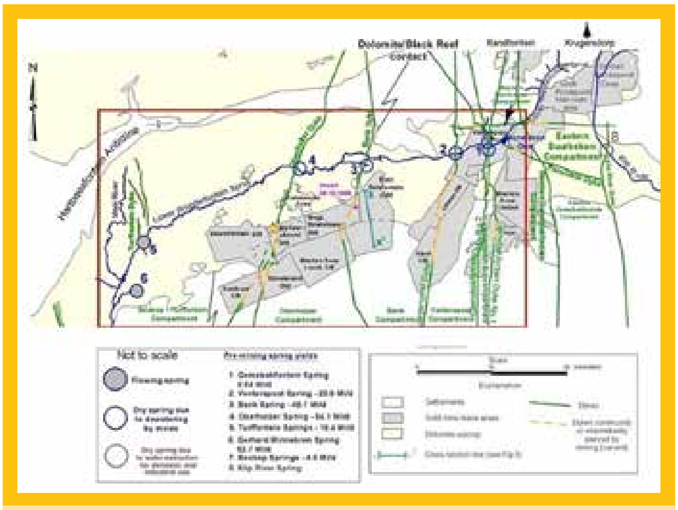

FIGURE 1: Map of the Mooi River catchment (Swart et al. 2003b)

and become part of the water supply for JB Marks Local Municipality. From the Boskop Dam, situated ±12 km north of Potchefstroom, water intended for purification and drinking purposes flows southwards, routed via an open-top cement canal on the western side of the Mooi River, from where it flows to the city's water purification plant (capacity 33.6 Mℓ/day) located to the west of the Potchefstroom Dam (Annadale and Nealer 2011). The Potchefstroom water treatment plants have been described as operating close to maximum capacity to meet consumer demand and has regular interruptions/ water shortages in some areas (Bult, Ikageng, Promosa, Dassierand, Potchindustria, CBD) (IDP 2019).

1.2. Threats to potable water resources quality

Activities upstream of the JB Marks Local Municipality treatment plant include agriculture, industrial, gold mining, urban areas, informal settlements and diamond digging in the Mooi River catchment (Barnard et al., 2013). Pressures on the Mooi River Catchment are growing amidst development and urban expansion around Potchefstroom as well as the West Rand District Municipality (WRDM) and Merafong City Local Municipality (Westonaria, Oberholzer and Carletonville and Khutsong) (Van Eeden et al. 2009; Van Eeden & Nealer 2011).

The threat from mining activities has been documented by several studies and monitoring programs between 2002 and 2017 which reported mining impacts on the surface water quality as well as sediments and wetlands (Wade et al. 2002; Coetzee et al. 2006; Barthel 2007; Winde 2010a; Winde 2010b; Winde 2011; Winde and Erasmus 2011; Barnard et al. 2013; Labuschagne 2017; Pretorius 2017). The main concern related to mining activity is the formation of acid mine drainage (AMD) and U contamination (Coetzee et al. 2006; Winde 2010, 2011; Winde and Erasmus 2011). Although the impact of mining on the water quality and sediments of the Wonderfontein Spruit has been known and studied thoroughly (Coetzee et al. 2006; Winde 2010a; Winde and Erasmus 2011; Winde 2011), water from the Upper Mooi River, before the confluence with the Wonderfontein Spruit, as well as the spring water of the Gerhard Minnebron (GMB) has always been considered to be almost pristine when compared to the Wonderfontein Spruit (Winde and Erasmus 2011; Winde 2011). However, recent studies showed a deterioration of the water quality at the springs in the un-dewatered Boskop-Turffontein compartment (Winde and Erasmus 2011; Winde 2011). Winde and Erasmus (2011) found a sharp increase in the radionuclides (U) load at the dolomitic springs which are linked to mining activities. A previously unknown linkage to the Wonderfontein Spruit via a network of underground karst channels in the un-dewatered Boskop-Turffontein compartment, which are in some way linked to deep level gold mining and/or sinkholes filled with mine tailings, were proposed (Winde and Erasmus 2011; Winde 2011).

A study by Dill et al. (2007) found that the past practice of backfilling of sinkholes with gold tailings has a high risk of causing impacts on the dolomite aquifer once mines close and dewatering of the dolomitic compartments are ceased. Dill et al. (2007) suggested that U levels of up to 300 mg/L are to be expected in leachate from tailings suggesting that tailings-filled sinkholes will be a major groundwater pollution risk. The World Health Organisation (WHO) limit for U in drinking water is 15 μg/ℓ (WHO 2006). Winde (2010a); Winde 2010b) and Winde and Erasmus (2011) reported an average U level downstream of the Wonderfontein Spruit between 55 and 79 μg/ℓ compared to the regional natural background of 0.8 μg/ℓ measured at the origin of the Mooi River at Bovenste Oog.

Pulles et al. (2005) suggested surface decanting of AMD is likely to occur to some degree in the Far West Rand after mining ceases and mine voids are flooded. In addition, the potential leaching of AMD from discard dumps such as tailings storage facilities (TSF) into the dolomitic aquifer is high (Dill et al. 2007). Although dolomite may neutralise the acidic metalliferous seepage related to mining, the armouring effect of dissolved iron in the AMD may result in a coating forming on the dolomite surfaces hindering dissolution rates and lowering the neutralisation potential (Dill et al. 2007). Modelling indicated that U would leach from tailings for 50 to 100 years (Dill et al. 2007).

Although the U load reaching the Boskop Dam is still considered relatively low compared to that in the Wonderfontein Spruit, the significant and persistent increase suggests a reason for concern. Should this trend continue significant U loads may contaminate the main water supply reservoir of JB Marks Local Municipality. Wetlands, such as that found around the springs are known to act as a passive water treatment system, removing harmful elements such as U and other contaminants from the water column by fixing it in the organic peat (Winde 2010; Winde and Erasmus 2011). However, Winde and Erasmus (2011) estimated that almost 60% of the peat in the wetland around the GMB has been extracted for potting soil and mushroom production. It is unknown to what extent the buffering function of the remaining peat deposits has been compromised.

1.3. Threats to potable water resources quantity

The post-mine closure water quality is, however, not the only concern when water security is considered. The availability of water to down-stream users (including JB Marks Local Municipality) will be influenced by the cessation of mining operations in the Far West Rand (Usher and Scott, 2001, Swart et al., 2003). Cessation of mining operations including cessation of pumping water from underground and disposing that into the Mooi River Catchment will not only have an immediate impact on the volume of surface water available to down-stream users, but it will over the long-term effectively lead to re-watering of the dolomitic compartments overlying the mine voids (Usher and Scott 2001; Swart et al. 2003).

Mining not only extensively augmented the underground storage capacity by creating voids in the rock beneath the dolomite, but mining through compartmentalising dykes effectively linked mine voids thereby changing the hydraulics of the system. This resulted in uncertainty on how the system will react once mines reach the end of their life span and pumping ceases (Usher and Scott 2001, Swart et al. 2003). Various authors attempted to model the time it will take for the mine void and de-watered dolomitic compartments to fill up naturally through infiltration from surface and estimated periods ranging from 30 years (Usher and Scott 2001, Swart et al. 2003) to 60 years (Jordaan et al. 1960; Lin and Lin 2014). However, these predictions are based on assumptions and remain largely untested. How the hydrogeologic system will react after the pumps are switched off is a topic of contention as two post mine closure scenarios have been proposed for the changed hydrogeological system: a mega-compartment scenario and a separate (pre-mining) compartment scenario.

In the mega-compartment scenario, it is proposed that mining, which pierced the dykes well below the actual karst aquifer, will hydraulically link the interconnected dewatered compartments and the downstream un-dewatered compartment resulting in a mega-compartment to form upon rewatering (Jordaan et al. 1960; Usher and Scott 2001; Swart et al. 2003). The underground connections will ultimately result in a single nearly horizontal water table which would cut across all the affected dolomitic compartments. Usher and Scott (2001) proposed that the water level in all the previously dewatered compartments will rise synchronously with a final water table in the mega-compartment remaining below its pre-mining level. This water level would be the elevation of the lowest lying springs i.e. the two Turffontein eyes, the GMB eye and possibly some smaller springs in the Boskop-Turffontein compartment, with karst springs in all upstream compartments remaining dry indefinitely despite re-watering of the karst aquifers. This scenario predicts a flow increase in the lowest lying Turffontein and GMB springs (combined pre-mining springs volume of 133 Mℓ/d) (Swart et al., 2003). However, polluted mine water would decant to surface from the mentioned springs (Usher and Scott 2001). This will therefore have implications for water quality in the JB Marks Local Municipality as water quality in the Mooi River would be compromised. Furthermore, this situation will not only have severe implications for post-mining water quality and availability but also land-use planning in the West Rand District Municipality and Merafong City Local Municipality (Jordaan et al. 1960; Usher and Scott 2001).

In the separate (pre-mining) compartment scenario the re-watering of the mine voids will be followed by a rapid rise of the water table through the fractured rock aquifer before the dewatered cavernous karst aquifer is filled (Swarts et al. 2003). The possibility that the volume of the mine void may be reduced over time due to the roof closing-in due to pressures generated by the overlying rock is considered (Winde et al. 2006; Van der Merwe & Madden 2002). This will restrict the flow of water between compartments making the formation of a mega-compartment impracticable. Swarts et al. (2003) predicted that the pre-mining differences between groundwater levels of adjacent compartments will be re-established resulting in groundwater intersecting the surface leading to the rejuvenation of the original natural springs of the Mooi River and Wonderfontein Spruit (Swarts et al. 2003). Swarts et al, (2003) also allude to the possibility that the flow at the springs may only be half of the original capacity as the void which needs to be filled is now larger as it includes the mine void and only

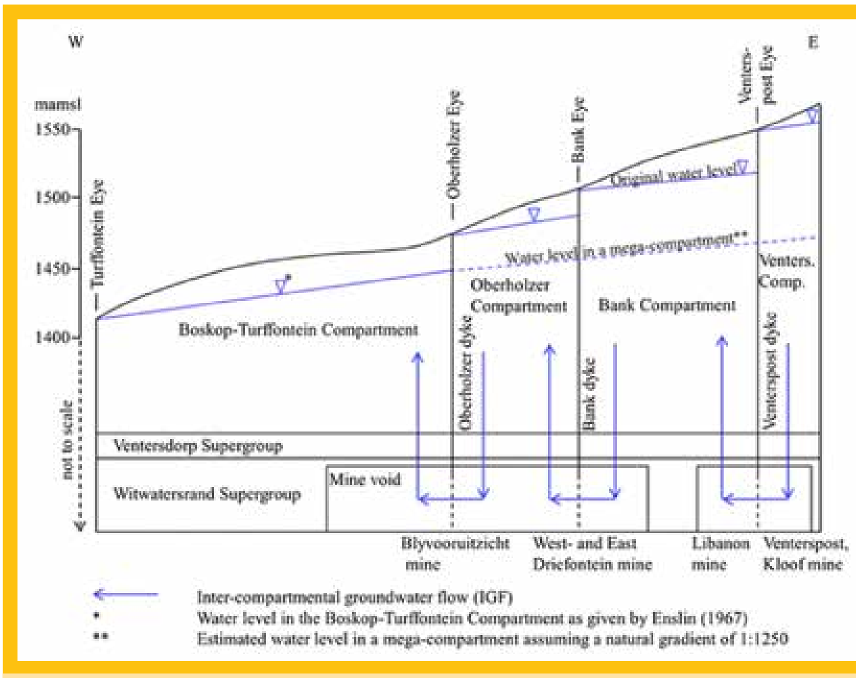

FIGURE 2: Conceptual model of the mega-compartment that could form in the FWR as a result of mining through impermeable dykes (Schrader et al. 2014)

during periods when the water level is sufficiently high will water flow from the springs.

Other impacts related to re-watering of the mine voids which might carry a risk to infrastructure and development in the area include:

Induced seismicity-
As production diminishes seismicity will decrease to background levels when mining operations ceases (Durrheim et al. 2006). However, seismicity is triggered by a rising water level in the mine void as water builds-up after cessation of pumping water to the surface (Cichowicz et al. 2016). Seismic events triggered by rising water level in mines that have been allowed to flood is likely to decrease once the water table in the mine void has stabilised (Durrheim et al. 2006; Cichowicz et al. 2016). Although further research on the link between seismicity and rising water levels are necessary, Durrheim et al. (2006) showed that it is unlikely that a seismic event triggered by a rising water table will have a greater magnitude than the events that occurred during mining. Although the damages from seismic activity around mining areas are small when compared to the damage experience in more seismic active areas around the world, damage to urban structures can be severe. Events with magnitudes exceeding 4 may cause some damage to buildings on the surface, while events with magnitudes exceeding 5 may cause serious damage (Durrheim et al. 2006). The risk of a seismic event on a mine causing damage to underground workings on a neighbouring mine depends on the distance between the focus of the event and vulnerable areas on the adjacent mines. There is some risk that a seismic event could cause movement on a fault surface transecting a water plug and/or water barrier pillar thereby opening up a fluid pathway which could cause flooding into populated mine workings (Durrheim et al. 2006).

Ground instability-
In addition to the potential threat to the water quality from sinkholes backfilled with tailings ground instability in the form of subsidence, dolines and sinkholes as a consequence of dewatering and lowering of the water table are a potential threat to infrastructure and development (Swart and van Schalkwyk 2001; Swart et al. 2003; Van Niekerk and van der Walt 2006; Richardson 2013; Schrader, Winde and Erasmus 2014; Schrader, Erasmus and Winde 2014; Constantinou and van Rooy 2018). Uncertainty regarding the potential for renewed instability exists as some studies suggest that no renewed instability will occur (Usher and Scott 2001) whereas other studies (Dill et al. 2007) propose reactivation of old sinkholes and development of new sinkholes (Swart et al., 2003; Van Niekerk and van der Walt 2006; Stoch and Winde 2010, Dill et al. 2007). Formation of dolines and sinkholes as well as re-activation of existing ones will pose a serious threat to important infrastructure such as the N12 highway and the main rail link between Pretoria and Cape Town (Dill et al. 2007; Phogole 2014).

2. CO-OPERATIVE GOVERNANCE

In the context of water security, the sustainability of the water supply from the Mooi River catchment is of concern. The Mooi River is exposed to many potential catchment related hazards that could seriously affect bulk water security of the JB Marks Local Municipality over an extended period of time. The municipality has the obligation to mitigate the impact of potential disasters within its boundaries (Disaster Management Act (Act 57 of 2002)). However, many of the impacts on the Mooi River catchment arise beyond the boundaries and control of the local municipality. This, however, does not relieve the municipality from the responsibility to develop and implement strategies to manage the risks. Effective risk management especially concerning the water quality and quantity is required.

Co-operative governance cuts across various governmental spheres. The Constitution (SA, 1996) stipulates a governance system that compels "all spheres of government and all organs of state" to co-operate with each other in "mutual trust and good faith". This should be taking place among all public sector departments, regardless of the activity and its location in the project cycle. The most important legislation, which has direct and important bearing on the environmental effects of mining, are the National Environmental Management Act NEMA of 1998 (Act, 107 of 1998), National Water Act (Act of 1998), Minerals and Petroleum Resources Development Act (MPRDA) (Act 28 of 2002). The NEMA (Act, 107 of 1998) and the National Water Act (Act 36 of 1998) support co-operative governance, for example, through the provision for arrangements such as catchment management agencies and environmental cooperation agreements.

3. REGIONAL MINE CLOSURE

Currently operating mines are required to rehabilitate any environmental damage that may occur during mining and to make financial provision for the rehabilitation of such damage (Mineral and Petroleum Resources Development Act (MPRDA) (Act 28 of 2002)). A closure certificate will be issued only if the Chief Inspector of Mines and other relevant government departments (Water and Sanitation, Environmental Affairs) are satisfied that provisions relating to health and safety and water pollution prevention/management including the pumping and treating of water, and compliance with the conditions of the environmental authorization as part of the environmental management plan have been addressed. This requirement by legislation was put in place to hold mining companies accountable for pollution impacts and to minimize government's liability of post-mine closure acid mine drainage decant. Most mining companies comply with the minimum requirements to environmental management and rehabilitation. However, additional challenges in governing mine closure were highlighted by the cumulative pollution decanting from the West Rand goldfield where mines are hydrologically interconnected and impacted on the environment through decanting of AMD from the lowest lying mine infrastructure (Hobbs and Cobbing 2007; McCarthy 2010; Durand 2012). The cumulative impact from all the mines in a region could therefore be imposed upon the last operating mine in the region, which could be held liable for the cumulative impact of all the mines. Furthermore, a number of large underground mines are interconnected and share the responsibility to dewater the mine voids (van Tonder et al. 2009). As different mines within a region will cease operations at different times the dewatering responsibility will rest on the remaining mines with the last operating mine bearing the rewatering liability for an entire mining region. It is therefore important to coordinate the cessation of mining activities to ensure proper apportionment of liability to the contributing mines within a region and to coordinate the potential socio-economic impact of mine closure on the community.

The trend in South Africa is that mines are placed on care and maintenance due to their inability to secure a closure certificate, particularly for large-scale mines.

The concept of the regional mine closure was born from the potential risks of cumulative environmental and socio-economic impact of interconnected mines in a region (van Tonder et al. 2009; Pulles et al. 2005). Regional mine closures therefore propose a new approach away from the historical site-specific mine closure to a more integrated approach where all mines in the region have to work together to limit environmental and socio-economic impacts (van Tonder et al. 2009).

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Due to the fact that most mines in the Far West Rand are hydrologically interconnected, this area is a good candidate for a coordinated plan or regional mine closure plan to be implemented as closure of one mine will impact on the remaining mines (van Tonder et al. 2009; Pulles et al. 2005). A good example is the Ezulwini operations seeking a closure certificate but was forced to continue pumping water to prevent flooding of the adjoining mining operations.

Furthermore, the regional mine closure strategy calls for the involvement of all affected local and district municipalities and national government departments to set a framework within which these mines can plan for mine closure (van Tonder et al. 2009).

The Constitution of the FWRDWA places the responsibility of reducing impacts and managing the water on all member mines until rewatering has been completed (Phogole, 2014).

4. CONCLUSION

This research highlights areas considered of utmost significance for the current and future municipal managers and officials who are tasked with the more effective, efficient and economic public management and delivery of potable water services within the demarcated municipal area of the JB Marks Local Municipality.

It is of utmost importance that the re-watering of the mine void in the FWR and the associated effects on the dolomitic compartments are well understood to avoid uncontrolled re-watering and pollution as seen in the West Rand. Where potential decant points of mining contaminated water will be and what the quality of this decanting water will be are still not confidently defined. The hypothesis that a mega-compartment will be formed that will have no impact on water security and treatment costs in the case of JB Marks Local Municipality is not the only possibility and due to geological mechanisms and forces in deep level mining should therefore not be the exclusive model used in post-rewatering impact planning. However, notwithstanding which scenario will be proven to be correct, the quality of eventual outflow will be highly contaminated, requiring additional cost in improving the quality through bulk water purification. It thus implies not only to ratepayers in terms of knock-on costs but for all governmental institutions depending on water sources in the entire Mooi River catchment, including users downstream of JB Marks Local Municipality eventually the Vaal River.

A steady deterioration of quality of water from the springs in the Boskop-Turffontein compartment as a direct consequence of mining and surface-ground water interaction is a forewarning of what can be expected over the rewatering period and for extended periods thereafter. Future generations and governmental organisations will be responsible to deal with lower quality (AMD, heavy metal and U contamination) of the bulk water supply of the JB Marks Local Municipality. The quality of raw water supply may require alternative technology processes for treatment not currently installed at the water treatment plant. The rewatering will thus result in financial implications in the delivery of bulk water services by JB Marks Local Municipality and local ratepayers.

The uncertainty regarding the re-watering of the mine void and overlying dolomitic aquifer highlights the risk of JB Marks Local Municipality losing part of its current bulk raw water supply. This uncertainty is therefore of concern as future sustainability of the municipality may be severely compromised if alternative water supply is not planned in time.

The degree to which ground stability will be affected by recovering water tables, possibly leading to the re-activation of existing sinkholes and formation of new sinkholes within the Far West Rand has not been quantified yet. Induced seismicity might have impacts on surface infrastructure not considered currently as the magnitude of potential future seismic activity has not been fixed.

Due to the trans-boundary water and instability issues cooperative governance between JB Marks Local Municipality, Merafong City Local Municipality, and the West Rand District Municipality and provincial as well as national governmental spheres are important for sustainable development in the region. As the karst aquifers are considered strategic water source areas (SWSAs) of national importance the integrated water resource management of this resource require involvement of all governmental spheres.

Although historic structures such as the FWRDWA and SCTC has the obligation to maintain control of the impacts of rewatering, the functioning of these committees is uncertain and cannot be considered as a safeguard against potential threats to water security and land stability. The proposed Regional Mine Closure strategy was not implemented leaving the question as to how mine closure is being coordinated and whether sufficient attention is paid to long-term impacts beyond the gold mining basin. The functioning of these structures along with cooperative governance on all spheres of government should be coordinated to safeguard water security of the JB Marks Local Municipality. However, no evidence could be found of prior research constructing a cooperative governance framework that could guide and assist mining companies in the Far West Rand in their decision-making and actions when dealing with the imminent mine closure and post-mining impacts on the region.

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