The Effectiveness of Upgrading the Van Ryn Canal as an Option to Reduce Water Ingress into the Underground Mine Workings in the East Rand of the Witwatersrand Basin in Gauteng Province, South Africa

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Abstract

The Van Ryn area in the East Rand Goldfield has been identified as an ingress zone. Previously, the Van Ryn Canal was developed to convey over the surface and above mine workings in the outcrop zone of the Witwatersrand Supergroup in the northern part of the goldfield. The canal had been damaged at various points and was repaired to prevent ponding of surface water and subsequent seepage into the subsurface. This study focuses on the findings of the effectiveness of repairing the canal to reduce the ingress volumes in the vicinity of the canal. Ingress of water in the Witwatersrand was being estimated using the volumes pumped from underground workings and the response of the water level to pumping.

Keywords: Van Ryn Canal, Ponding, Pumping, Volume, Ingress.

Introduction

Gold mining activities in the Witwatersrand Goldfields have been ongoing for over 100 years following the discovery of gold in this area in the late 1800s. The mining initially focused on reef outcrops and shallow gold reefs, followed by deeper mining, south of the reef outcrops (Tucker *et al*., 2016). These mining activities have left some serious legacy issues that need to be addressed. Some of these issues are attributed to the cessation of operations of gold mines within the area. Unfortunately, as with most mining operations, these extensive mining activities had negative environmental impacts characterised by a change in landscape, surface, groundwater, soil pollution, and subsidence, amongst others. Abandoned mine shafts and natural subsidence exacerbated by illegal mining activities to scavenge the leftover ore have resulted in water ingress into the underground mined-out areas flooding the mine voids in the East, West, and Central Rand basins. As a result of flooding, high volumes of acidic mine water with elevated sulfate and metal loads started discharging in the West Rand Basin with a high risk of discharge from the other two basins before the short-term intervention measures were put in place. Three High-Density Sludge (HDS) treatment plants were established to protect the downstream environment in the three original Witwatersrand Goldfields by neutralising acid water and precipitating metals. In addition, one of the recommendations adopted by the Inter-Ministerial Committee (IMC) on Acid Mine Drainage was to reduce the water ingress volumes to facilitate the effective management of mine water in the long term as well as saving costs on pumping and treating mine water. Ingress control can be achieved by preventing the direct flow of water into mine openings and the recharge of the shallow groundwater above the mine void. The prevention of water ingress can be achieved by, *inter alia*, building canals to divert the flow of surface streams and sealing of cracks and mine openings. The prevention of water ingress into the mine voids is beneficial in that it:

- Keeps clean water clean;
- reduces the rate at which mine workings flood;
- reduces the volume of water to be pumped out of mine workings; and
- reduces the costs associated with the cleaning of pumped-out water before it is released back to the natural environment (Marubini *et al*., 2011).

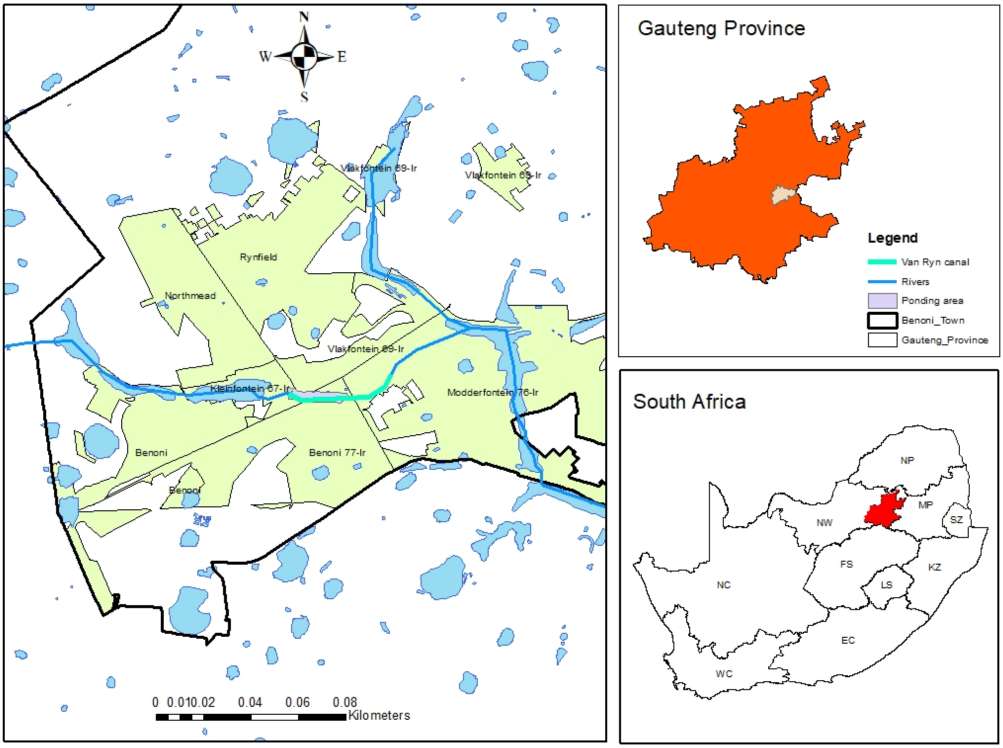

Figure 1 *The locality map of the Van Ryn area.*

Study area

Extensive work has been conducted on mine water ingress (Barradas *et al.*, 1996; Nkabinde *et al.*, 2005; Oryx Environmental & Limited, 2004; Scott, 1995; Vivier *et al.*, 2006; Zitholele Consulting, 2005). The Van Ryn area has been identified as an ingress zone (Marubini *et al.*, 2011; Marubini & Nemaxwi, 2012) and studies to confirm and measure ingress volume was carried out by (Tegegn *et al.* 2017). Topographical and geotechnical engineering surveys were conducted to assist with the design of the canal.

In 2011, the Interministerial Committee on AMD recommended that ingress control measures be implemented to reduce surface water ingress into the mine voids. In this case, upgrading an existing channel was recommended as an implementation option to reduce surface water ingress. The canal was damaged at various points and was in a state of disrepair. The stream flowing through the canal was diverted to the north at the inlet below Snake Road to form the Van Ryn pond (Fig.2) to accommodate the maintenance works.

The 1 in 10-year flood event was determined for the canal route. An earth-lined design was determined to be the best suited to the channel and the most cost-effective (Tazu, 2017). The earth canal was reshaped and required structures including gabions to reinforce the downstream side of the embankment constructed (Fig. 3) and all design layers were subsequently completed. A 2100 × 1200 mm, Class 100s culvert portal was installed, replacing the smaller culverts which were contributing to ponding in the area. The canal has a length of 1734 m and a normal base of 10 m.

Collection of pumping data and water levels

The Department of Water and Sanitation has appointed Trans Caledon Tunnel Authority (TCTA) to implement a short-term solution by pumping water from the mine voids in the Witwatersrand Basin. The data is recorded from the pumping station daily (Fig. 4). The two parameters of interest are the volume of

Figure 2 Diversion of the old channel flow to form ponding/dam.

water being pumped from the mine voids and the water levels (Coetzee *et al.* 2021).

Data provided from the pumping station

To determine long-term average values, an ingress estimation method based on determining the average volume pumped between two dates with the same water level was selected for long measurement periods or a method based on linear interpolation of water level change and pumped volume The measurement period has been extended into the preceding (2017/18) hydrological year (Madzivire *et al.*, 2022)

Results and discussions

Estimates of ingress volume show a decrease following the completion of the Van Ryn Canal in October 2020, relative to baseline values determined for the 2017/18–2019/20 hydrological years (1 October to 30 September). In this basin water has been pumped since June 2016. The pumping record shows a period from September 2018 – February 2019 (Fig. 5) when water could not be pumped due to technical problems encountered at the pumping station. The rapid changes in water level during 2020 and 2021 occurred as the pumps were

Figure 3 Completed earth canal with a downstream gabion wall

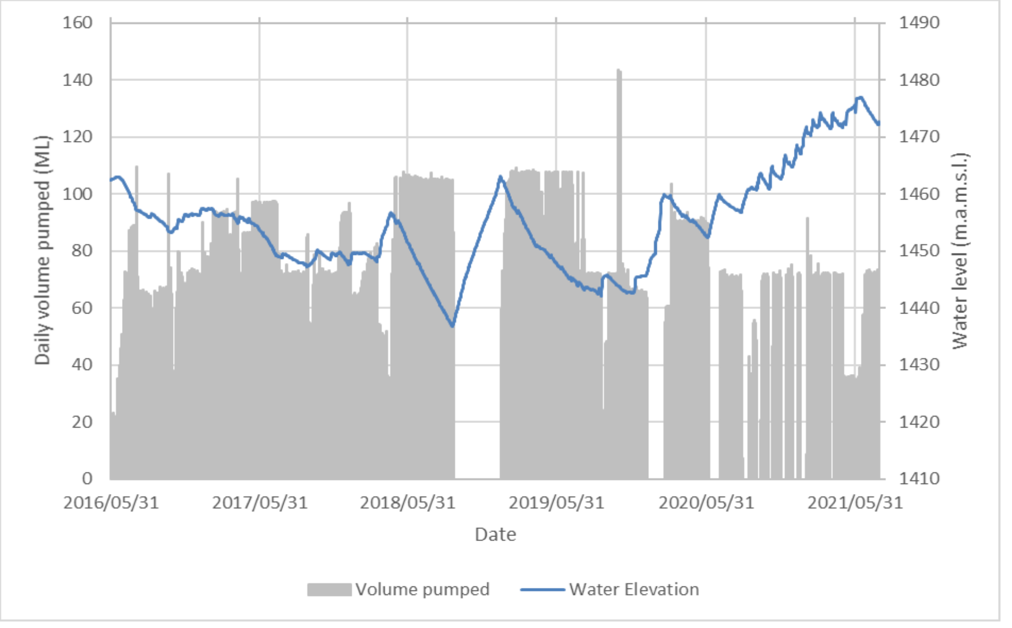

Figure 4 *Daily water levels and pumped volumes for the Eastern Basin.*

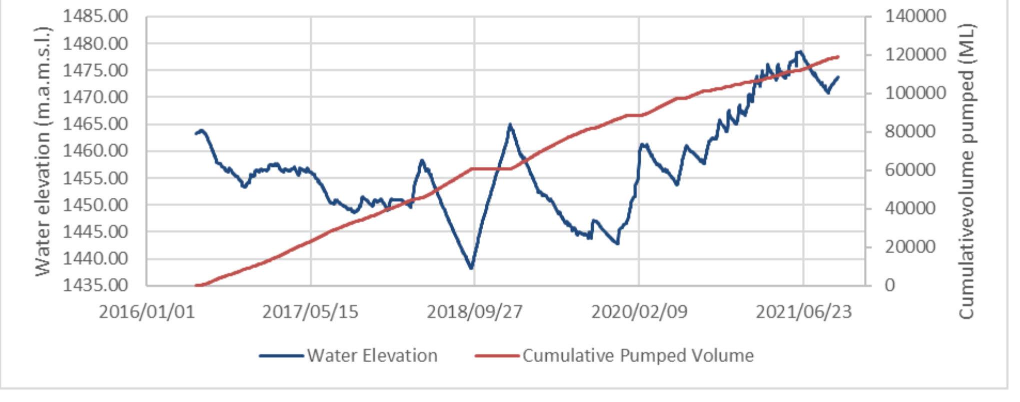

Figure 5 *Water level and cumulative pumped volume from the Eastern Basin from 31 May 2016 to 25 August 2021.*

periodically stopped to allow sludge disposal at the pumping shaft.

Average daily ingress volumes have been calculated on a year-by-year basis, using the linear interpolation method (Fig. 6). This shows average daily ingress of approximately 70 ML/d, for normal and high rainfall years, a reduced ingress rate for the 2018/19 drought year and a further reduction for the 2020/21 hydrological year.

The results post the completion of the repairs of the Van Ryn Canal show ingress reduction in the Eastern Basin as indicated in (Table 1) and (Fig. 7). Therefore, the implementation option recommended for the Van Ryn Canal is effective.

Conclusions

In the Eastern Basin, data collected for one hydrological year following the completion of the Van Ryn Canal indicates that there has been a reduction in daily ingress volume which also allowed the water level to be controlled during the 2020/21 hydrological

Figure 6 *Ingress estimates for the Eastern Basin, using the linear interpolation method for the 2016/7–2020/1 hydrological years, up to 17 May 2021.*

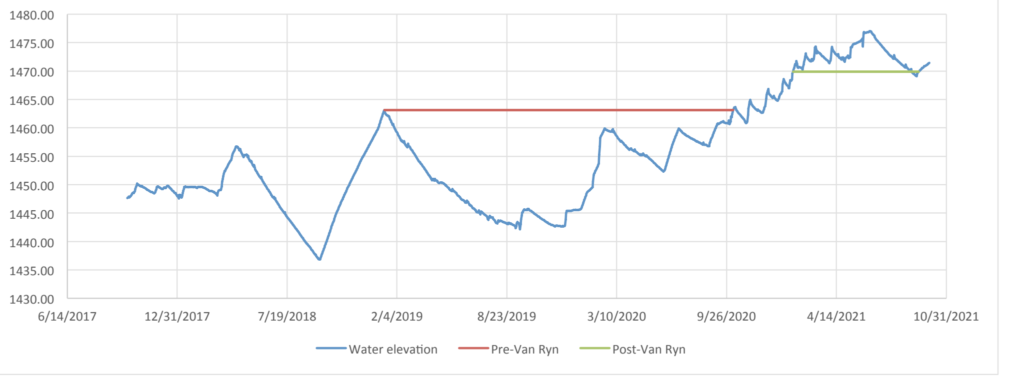

Figure 7 *Results of the pumping rates.*

Table 1 *Results of flow estimation using the* $h_{t1} = h_{t2}$ *method for the Eastern Basin.*

	Start date	End date	No. of days	Start level (m.a.m.s.l)	End level (m.a.m.s.l)	Diff. level (m)	Mean level (m.a.m.s.l)	Volume pumped (ML)	Daily ingress rate (ML/d)
Pre-Van Ryn	2019/01/12	2020/10/08	635	1 463.14	1 463.16	0.02	1 451.84	41 525.6	65.4
Post-Van Ryn	2021/01/25	2021/09/11	229	1 469.88	1 469.93	0.05	1 472.84	11 740.5	51.3

year. Controlling the water level in the underground mine workings will assist in planning for raising the environmental critical level (ECL). Before the completion of the Van Ryn Canal, the daily ingress volume was recorded as 65.4 ML/d, and post completion of the canal the daily ingress volume is 51.3 ML/d (Madzivire *et al.*, 2021).

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