Exploring a New Water Economy Post Mining in a Coal Mining Region

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Abstract

The study investigated the opportunity for a new water economy in Mpumalanga, South Africa, as coal mines close and coal-fired power generation is decommissioned. Study findings indicate that about 434 Mm^3/a of water will become available. This includes 117 Mm^3/a raw water from coal-fired power operations, 224 Mm^3/a of mining-influenced water and 93 Mm^3/a of treated municipal effluent. This water exhibits variable qualities due to mining and industrial impacts and is unsuitable for direct use without treatment. Reuse of treated water for irrigation offers the most immediate and cost-effective pathway while green hydrogen production represents a promising long-term opportunity.

Keywords: Coal mining, irrigation, green hydrogen, coal-fired power, water reuse

Introduction

For over a century, coal has driven South Africa's economic development by supporting electricity generation, industrialisation, mining, manufacturing, and urbanisation. Affordable coal-based energy has enabled economic growth and employment but also contributed to significant environmental and water management challenges including structural dependence on coal-based energy systems (Staffell *et al*., 2019).

Mpumalanga plays a central role in South Africa's coal economy, producing most of the country's coal and hosting the majority of coal-fired power stations. This coal-dependent development pathway has supported economic growth, employment, and infrastructure but increased resource dependency and environmental pressures, particularly on water resources. As South Africa transitions from coal, the province faces major economic, social, and environmental restructuring challenges.

Water is central to Mpumalanga's coal-based economy, as coal mining and coal-fired power generation require substantial volumes for mining, beneficiation, dust suppression, cooling, and emissions control. Historically, extensive surface water, groundwater, and inter-basin transfers supported these activities, increasing long-term dependence on imported water and altering natural hydrological systems.

Mining-influenced water (MIW) is among the most significant and persistent environmental legacies of coal mining in Mpumalanga, posing long-term risks to water quality, ecosystem health, and sustainable water resource management. However, several studies have demonstrated that a number of treatment technologies, sustainable management strategies and regulatory measures addressing the magnitude and complexity of MIW management have been developed (Mogashane *et al*. 2025). A significant milestone was achieved in 2005 with the completion of the eMalahleni Water Reclamation facility, the world's first plant to supply purified MIW to a municipality (Gunther & Mey, 2008).

As part of South Africa's Just Energy Transition (JET) seeking to decarbonise industrial operations while addressing social equity, regional inequality and environmental restoration, the Integrated Resource Plan projects the retirement of approximately

10 GW of coal-fired generation capacity by 2030, with further decommissioning thereafter, leaving only 2 operational coal-fired power stations by 2040 (DMRE, 2023). Such developments are expected to result in the closure of coal mines supplying coal-fired power operations and reduced water abstraction associated with mining and power generation.

This study assessed the emergence of a new water economy as coal mines close and coal-fired power generation is decommissioned in Mpumalanga. The study advances existing mine water research by integrating water release from energy decommissioning with regional economic modelling, enabling direct comparison of water reuse pathways in a post-coal context.

Study Area

Figure 1 shows the case study area (Mpumalanga Province), located on the northeastern part of South Africa. Mpumalanga falls within three major water management regions: the Upper Olifants Catchment Area, Upper Vaal Catchment Area, and the Inkomati–Usuthu Water Management Area. Each region has distinct hydrological and economic characteristics and management challenges, yet collectively they underpin the provincial water economy and provide the spatial framework for this study.

Methods

An assessment was undertaken to identify various water resources that will become available as coal mines close and coal-fired power stations are decommissioned. Data on the water resources were obtained from different water users within the case study province, with three primary water resources identified for the assessment. Each water resource was assessed in terms of its potential quantity, quality and reuse for productive purposes.

An economic modelling approach was applied to assess the economic value of water in supporting an irrigation pathway and estimate how increased water inputs could contribute to regional GDP growth and employment

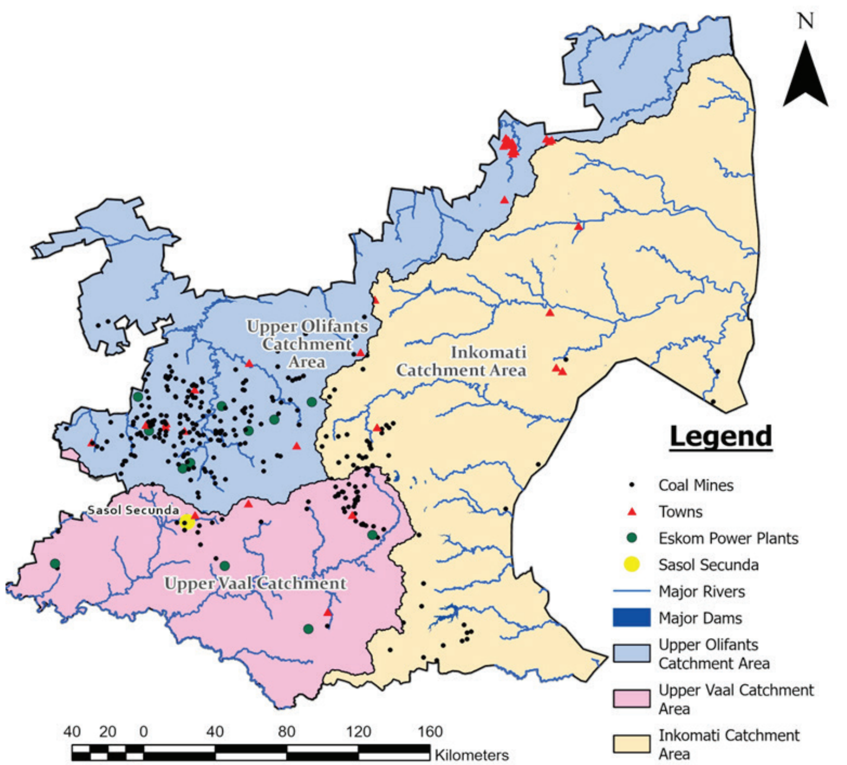

Figure 1 *Study area and its land use activities.*

creation through sectoral multiplier effects. This model was based on a Social Accounting Matrix (SAM) framework, which tracks the flow of income and expenditure between different sectors of the economy, including intersectoral transactions, taxes, value added, and compensation to employees. The modelling assumes that historical economic relationships and multipliers represented within the SAM remain broadly applicable under future development conditions. Employment impacts were estimated based on changes in compensation to employees and therefore represent aggregate employment related benefits rather than disaggregated job categories or skill levels.

Results and Discussion

Current water use patterns in Mpumalanga

Mpumalanga's water governance is challenged by weak institutional capacity, delayed water licensing, fragmented regulation, and competing demands from mining, agriculture, and municipalities. Historical users retain dominant access to water, while enforcement and monitoring remain inadequate. These governance gaps hinder equitable allocation, pollution control, and effective management of water and water scarcity (Helen Suzman Foundation, 2026).

Agriculture remains the largest water user, accounting for approximately 1 434 Mm^3/a, with the Inkomati–Usuthu WMA alone responsible for about 1 069 Mm^3/a. Irrigated agriculture in this region is dominated by sugarcane, citrus, and other subtropical crops that is highly dependent on regulated river abstractions and dam releases. Forestry constitutes a further major water consumer, with an estimated 450 Mm^3/a lost primarily through evapotranspiration, significantly reducing runoff and groundwater recharge, especially within the Inkomati–Usuthu WMA. Power generation has historically been a major strategic water user in Mpumalanga. Coal-fired power stations currently consume approximately 214 Mm^3/a for cooling, boiler feed, and flue gas desulfurisation. Manufacturing uses a further 179 Mm^3/a, largely concentrated in the Upper Vaal Catchment Area and driven by large industrial operations, which are expected to increase their direct water demand in the medium term (Sasol Limited, 2023).

Municipal and domestic water use amounts to approximately 202 Mm^3/a, but system inefficiencies significantly reduce effective supply. Non-revenue water losses of around 40%, largely due to ageing infrastructure and operational challenges, represent a major opportunity for demand management and water recovery (DWS, 2024).

Water release through coal-fired power stations decommissioning

The decommissioning of coal-fired power stations under South Africa's JET presents a substantial opportunity for reallocating released raw water. Table 1 provides a breakdown of the projected water demand associated with power generation up to 2035. From Table 1 the total water demand is projected to reduce to 97.4 Mm^3/a by 2035 compared to a demand of 214.1 Mm^3/a in 2024, thereby releasing about 117 Mm^3/a. By 2050, cumulative releases from all decommissioned stations are projected to reach between 200 and 245 Mm^3/a. Individual power stations such as power stations A, B, E, and H are projected to reduce water use by more than 90%, highlighting the scale of potential reallocation (Eskom, 2024). This positions power generation released water as a strategic input into a future water economy that can potentially support economic diversification and regional resilience.

Raw water is generally of relatively high quality, having been supplied through regulated inter-basin transfer schemes and managed bulk water systems. Typical raw water quality in these systems includes pH values ranging from approximately 6.5 to 8.5, total dissolved solids (TDS) concentrations between 150 and 400 mg/L, sulphate concentrations generally below 250 mg/L, and relatively low concentrations of iron and manganese (Ngamlana *et al*, 2024). These characteristics mean that the water is generally suitable for irrigation with minimal treatment requirements, although localized salinity or hardness adjustment may occasionally be necessary depending on crop sensitivity and irrigation method.

Table 1 Coal-fired power stations projected water demand for the year 2035 (Eskom, 2024).

Power station	Coal-fired power stations water demand estimates (Mm^3/a)	
	2024	2035
A	13.3	1.3
B	25.3	1.9
C	26.1	10.0
D	2.6	2.6
E	29.6	3.1
F	37.6	14.5
G	8.7	13.3
H	16.1	0.4
I	20.0	14.7
J	26.7	24.5
K	8.1	11.1
Total	214.1	97.4

Table 2 Mining-influenced water discharge in Mpumalanga by catchment (WARMS, 2023).

Discharge Method	Upper Olifants (Mm^3/a)	Upper Vaal (Mm^3/a)	Inkomati-Usuthu (Mm^3/a)
Discharge into rivers	163.5	11.5	35.1
Point Source Discharge	13.3	0.17	0.40
Total	176.8	11.7	35.5

Coal mining and mining-influenced water as a recoverable resource

Although coal mining uses a relatively modest volume of raw water compared to agriculture and power generation, its legacy impact on water resources is substantial. Coal mining in Mpumalanga generates approximately 224 Mm^3/a of MIW with the Upper Olifants Catchment Area recording the highest volumes, followed by the Inkomati–Usuthu WMA and then the Upper Vaal catchment Area as given in Table 2 (WARMS, 2023). While only a small proportion is discharged directly into rivers, extensive use of rivers for discharging excess MIW creates cumulative water quality risks and long-term environmental liabilities.

MIW in Mpumalanga coalfields typically exhibits substantially poorer water quality due to prolonged interaction with exposed geological materials, underground workings, and mine residue deposits. Typical MIW quality includes pH values between approximately 2.5 and 7.5, TDS concentrations ranging from about 1 500 to 6 000 mg/L, sulphate concentrations between 500 and 3 500 mg/L, hardness concentrations between 300 and 2 000 mg/L as $CaCO_3$, iron concentrations ranging from 1 to 200 mg/L, and manganese concentrations between 0.5 and 50 mg/L (Matebese *et al.*, 2024). These concentrations commonly exceed irrigation and industrial reuse thresholds. For irrigation reuse, South African water quality guidelines generally recommend long term TDS concentrations below approximately 450 mg/L and sulphate concentrations below approximately 200 mg/L for sensitive crops (Du Plessis *et al.* 2017). Elevated sulphates and TDS may contribute to soil salinisation and reduced crop productivity, while elevated metals may create toxicity risks and long-term accumulation in soils. Consequently, untreated MIW is generally unsuitable for irrigation and requires treatment before reuse.

Treated municipal wastewater effluent

Mpumalanga province hosts about 76 municipal wastewater treatment plants (WWTPs) treating and discharging approximately 93 Mm^3/a into the water resource (DWS Green Drop Report, 2022). This water can be redirected for reuse purposes, however, the effluent quality is highly variable (Malakane & Maphanga 2024), with many plants not fully compliant due to operational inefficiencies, therefore requiring additional treatment for reuse purposes.

Treatment technologies and cost implications

The assessment of treatment technologies confirms that available water resources can be transformed into usable resources across a range of applications. Neutralisation using lime and limestone was identified as the most cost-effective option for treating large volumes of MIW at an estimated cost of R5.68/m^3 (USD 0.34/m^3) for non-potable uses. Biological sulphate removal offers enhanced sulphate reduction and broader industrial reuse potential, albeit at higher operational complexity and costs of around R7.40/m^3 (USD 0.45/m^3). Reverse osmosis (RO) remains essential for high-purity applications, including green hydrogen production, but at a significantly higher cost of approximately R18.61/m^3 (USD 1.13/m^3). In this regard, the eMalahleni Water Reclamation Plant represents a full scale RO plant implemented in Mpumalanga, and is currently recovering potable water from MIW sourced from several mines in the eMalahleni area (Gunther & Mey, 2008).

Economic opportunities and strategic pathways

Overall, an estimated 434 Mm^3/a of water is expected to become available in Mpumalanga through the combined effects of coal-fired power generation decommissioning, mine closure, and treated municipal effluent discharges.

The results of the economic modelling based on the SAM framework indicates that redirecting treated water to irrigation offers the most immediate and cost-effective development pathway. In this regard, reusing approximately 224 Mm^3/a for irrigation has the potential to create more than 16 000 jobs, generate R3 billion worth of direct value addition and a total economic output exceeding R26 billion when multiplier effects are considered. However, these results should be interpreted as indicative ranges of potential economic outcomes rather than precise forecasts, as they remain subject to uncertainty associated with future market conditions, infrastructure availability, policy developments, technological change, and limitations in the availability and quality of economic and water use data. Nonetheless, the irrigation pathway presents an option that supports food security, economic revitalisation and employment creation in areas affected by mine closures.

Green hydrogen production represents a longer-term strategic opportunity aligned with low-carbon industrial development. However, its feasibility depends not only on water availability and quality but also on the parallel development of renewable energy, electrolyser capacity, and supporting infrastructure. While Mpumalanga's existing grid and industrial base provide advantages for green hydrogen as a pathway, irrigation remains the most practical near-term option for maximising socio-economic benefits.

Conclusions

Mpumalanga is expected to face significant economic, environmental and social changes as South Africa moves away from coal-based energy. The study shows that water currently used in coal mining and power generation, including mining-influenced water and treated municipal effluent, could support future economic activities through productive reuse. Irrigation presents the most immediate opportunity, while green hydrogen may offer longer-term industrial potential. Achieving this transition will however require careful planning across water, energy and land-use sectors, together with improved governance, regulatory reform, and investment in water treatment and reuse infrastructure to support sustainable regional development and long-term water security.

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