PROJECT TITLE

SURFACE WATER AND GROUNDWATER RESOURCES MONITORING, CRADLE OF HUMANKIND WORLD HERITAGE SITE, GAUTENG PROVINCE, SOUTH AFRICA

REPORT TITLE

WATER RESOURCES STATUS REPORT FOR THE PERIOD APRIL 2024 TO SEPTEMBER 2024

PROJECT No.

GT/WHS/021/2022

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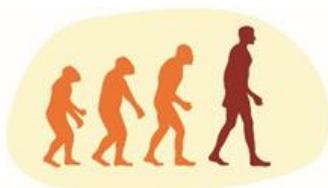
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PREPARED BY

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SUMMARY

Following the conclusion of the bid GT/WHS/021/2022, the Management Authority (MA) of the Cradle of Humanity World Heritage Site (COHWHS) selected the CSIR as the preferred service provider to carry out the water resources monitoring programme of the site. The programme commenced in 2012 as a follow-up to project BIQ005/2008, which was commissioned to create a water resources monitoring programme for the COHWHS property. Since its commencement, twenty (20) biannual *status quo* reports have been produced, including those compiled during the 2017 - 2020 phase of the monitoring programme under the project GT/GDED/092/2017. This report, which spans the months of April 2024 to September 2024, is the twenty-first (21st) of its kind. Notably, there exists a 2-year gap in the monitoring programme between the finalization and closure of project GT/GDED/092/2017 in September 2020 and the commencement of the monitoring programme under project GT/WHS/021/2022 in September 2022. Although efforts have been made to 'close the gap' by way of data collection from relevant stakeholders who continued their respective monitoring activities during this period, there remain gaps of permanently missing data which may compromise the holistic understanding of the COHWHS hydro(geo)logical environment and the various linkages between its surface water and groundwater systems.

Nonetheless, the assessment of impacts on the water resources environment of the COHWHS property takes on a comprehensive approach noting the conceptual hydrophysical and hydrochemical model developed for the COHWHS property in the Situation Assessment Report (Hobbs, 2011) and pays particular attention to those resources that are conceptually understood to be most at risk. In the context of the COHWHS, focus is placed on wastewater sources of which mine water (*aka* acid mine/rock drainage) rising in the Western Basin, and local municipal effluent discharged from Mogale City's Percy Stewart Wastewater Treatment Works, are of primary concern.

The outcome of monitoring activities as documented in the 21st *Status Quo* report has revealed the following key aspects of the water resources environment of the COHWHS:

- The COHWHS has experienced a significant decrease (~51%) in rainfall between 2023 and 2024, with the 2024 wet season rainfall at station HDS being 55% lower and ranking in the 7th percentile of the historical dataset.

- No rainfall samples from the DWS rainfall monitoring stations have been available since January 2024.

- Noting the missing data, the total rainfall for the 2024 hydrological year has resulted in a discharge volume of ~26.3 Mm³ which is ~66% less than the ~77.5 Mm³ discharge of the 2023 hydrological year.

- Static groundwater levels are stable in the southern segment of the COHWHS property, while a slight decrease is evident in groundwater level elevations in the central and the northern segments.

- The September 2024 static groundwater level of the Sterkfontein Cave lakes shows an apparent 0.65 m decrease since March 2023.

- Consistent with previous reports, the highest producing springs are the Zwartkrans, Nouklip and

Nash springs with apparent discharges of 21.06 ML/d, 8.44 ML/d and 10.29 ML/d, respectively. There is however a level of uncertainty in these measurements due to continuous and direct extraction at the springs' sources and turbulence over rocky streambeds.

- On the Tweelopiespruit, the pH values at the Hippo and Brickworks (F11S12) dams show a gradually increasing trend, with the downstream Brickworks Dam remaining predominantly acidic at a common pH of 4.7. Additionally, while the SEC values are decreasing at both sites, sulphate concentrations remain stable, iron levels at the Hippo Dam are slightly increasing, manganese concentrations are decreasing, and uranium levels have been consistent at 0.02 mg/L since March 2020.

- The trendlines from April 2024 to September 2024 indicate that sulphate levels in ambient groundwater have generally reduced across the DWS groundwater stations. There is however variability at individual stations and typically the sulphate values at the north-eastern end of the study area are lower than at the sites closer to the mine locations.

- In contrast to the acidic Tweelopiespruit and Rietspruit, the Blougatspruit and Bloubankspruit exhibit relatively higher alkalinity, with pH values consistently ranging from 7.2 to 7.9.

- The most recent microbiological analyses of surface water samples collected at sampling sites upstream and ~1 km downstream of Percy Stewart WWTW, as well as further downstream (>5km) confirm the faecal contamination of surface water along the Blougatspruit and Bloubankspruit. The most severe pollution is noted downstream of Percy Stewart WWTW along the Blougatspruit and Bloubankspruit where the MPN count for *E.coli* consistently exceeds 2419.6 per 100mL.

- The microbiological quality of the water from the Sterkfontein Cave lake is compromised by the increased total coliform bacteria and *E.coli* which exceeds the standard health-related limits across all sample results and thus reflects the impact of poorer quality surface water on the karst groundwater.

- The water from the major dolomitic springs is of excellent quality for all the parameters (i.e. pH, SEC, Ca, Mg, Na, K, Cl, SO_4, HCO_3, NO_3+NO_2, Si, Fe, Mn and Al) reported for September 2024 sampling results, with the exception of the Zwartkrans and Aquamine springs. The chemical results from the Zwartkrans Spring show probable mine water impact as evidenced by the high sulphate content and the Aquamine spring show pronounced concentrations of manganese, iron and aluminium, which may reflect the interaction with the surrounding geology.

- Across all the spring sample results, the microbiological quality of the water is compromised by the total coliform bacteria which far exceeds the standard health-related limits. *E.coli* concentrations measure at <1.0 MPN/100 mL for most of the springs indicating low risk, however the elevated *E.coli* counts measured in September 2024 at the Kromdraai, Tweefontein and Nash Spring categorised the springs as 'moderate to high risk. It is uncharacteristic for the Nash Spring to have an elevated *E.coli* count, therefore additional sampling is required at this site to investigate the anomalous results.

- Water samples collected in June 2024 from the Bloubankspruit showed no significant toxicity hazards, however in September 2024, both the Bloubankspruit and Skeerpoort Rivers exhibited acute toxicity hazards and signs of pollution, including elevated bacterial and algal growth.

The reduced quantity and deteriorating quality of surface and groundwater resources, exacerbated by low rainfall, acidic discharge and faecal contamination, pose significant environmental and public health risks. The environmental impact extends to the fossil sites within the COHWHS, as altered water chemistry and contamination can threaten the preservation of these important paleontological resources, potentially leading to accelerated degradation and loss of critical fossil evidence. Therefore, the results of these monitoring activities provide crucial information for the State of Conservation (SOC) of the property, which remains a key concern for UNESCO's World Heritage Centre due to its implications for the Outstanding Universal Value (OUV) of the COHWHS.

WATER RESOURCES STATUS REPORT FOR THE PERIOD APRIL 2024 TO SEPTEMBER 2024

TABLES

FIGURES

SYMBOLS, ACRONYMS & ABBREVIATIONS

~	approximately
>	greater than
<	less than
%	per cent (parts per hundred)
%ile	percentile
°C	degree(s) Celsius
Δh	change in head
a_h	hydrological year
aka	also known as
AMD	acid mine drainage
amsl	above mean sea level
ASPT	average score per taxon
bc	below collar
bs	below surface
C_5	concentration exceeded 95% of the time (5%ile)
C_{95}	concentration exceeded 5% of the time (95%ile)
ca.	*Circa* (about)
COHWHS	Cradle of Humankind World Heritage Site (*aka* 'the property')
CoV	coefficient of variation
CPOM	coarse particulate organic matter
CSIR	Council for Scientific and Industrial Research
DWS	Department of Water & Sanitation [formerly the Department of Water Affairs (DWA)]
EC	electrical conductivity
EoP	end-of-pipe
FFG	functional feeding group
FPOM	fine particulate organic matter
HDS	high density sludge
IHAS	integrated habitat assessment system
kg	kilogram(s)
km	kilometre(s)
L/d	litre(s) per day
L/s	litre(s) per second
L/s/km	litre(s) per second per kilometre
m	metre(s)
MA	Management Authority
meq/L	milliequivalent(s) per litre
mg/L	milligram(s) per litre
ML/d	megalitre(s) per day
mm	millimetre(s)

m^3/s	cubic metre(s) per second
Mm^3	million cubic metre(s)
Mm^3/a	million cubic metres per annum
MPN	most probable number
mS/m	milli Siemens per metre
n	count
n.s.	not specified
pp	pages
Q_{50}	discharge exceeded 50% of the time (50%ile or median)
REGM	Randfontein Estates Gold Mine
RU	Rand Uranium (earlier owner of the original REGM)
SASS	South African Scoring System
SD	standard deviation
SDM	synoptic discharge measurement
SEC	specific electrical conductance (electrical conductivity or EC @ 25°C)
SOC	State of Conservation
SRP	strategic research project
SS	Sibanye-Stillwater (formerly SibanyeGold and current owner of the original REGM)
TCTA	Trans-Caledon Tunnel Authority
TDS	total dissolved solids
USEPA	United States Environmental Protection Agency
UNESCO	United Nations Educational, Science and Cultural Organisation
WHC	World Heritage Committee (could also denote World Heritage Centre)
WWTW	wastewater treatment works

1 INTRODUCTION, BACKGROUND & CONTEXT

The Management Authority (MA) of the Cradle of Humankind World Heritage Site (COHWHS) appointed the CSIR to serve as service provider for the water resources monitoring programme of the property (Figure 1) following the outcome of bid GT/WHS/021/2022. Since its inception in 2012, the monitoring programme has, to date, generated twenty (20) bi-annual *status quo* reports (i.e. Hobbs, 2012; 2013a; 2013b; 2014a; 2014b; 2015a; 2015b; 2016a; 2016b; 2017a; 2017b; Hobbs *et al.*, 2018; Bugan *et al.*, 2018, Bugan *et al.*, 2019, Mvandaba *et al.* 2019, Mvandaba *et al.*, 2020a, Mvandaba *et al.* 2020b, Mvandaba *et al.* 2023a, b and Mvandaba and Moloi, 2024). This document represents the twenty-first (21st) such report and covers the period from April 2024 to September 2024.
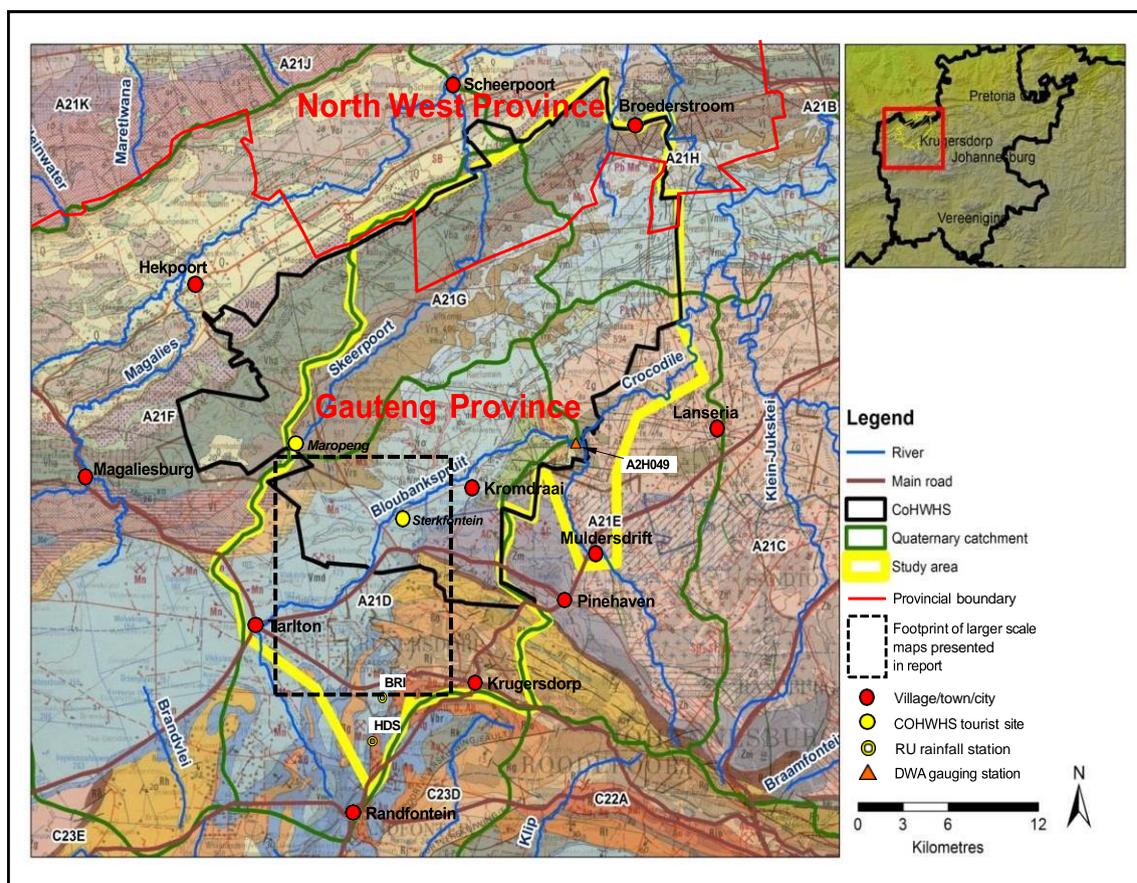
Figure 1   A map of the study area showing the regional geology, surface water drainages, quaternary catchments and other geographic locations for orientation.

2   TIMELINE OF KEY EVENTS

An updated timeline of key events since the start of mine water decanting in 2002, and incorporating the reporting period, is presented in **Figure 2**. The most recent landmark event on the timeline is the completion of a fourth State of Conservation (SOC) report (DEA, 2022) that was submitted to the United Nations Educational, Scientific and Cultural Organizations (UNESCO) World Heritage Centre (WHC) for consideration by the World Heritage Committee. The outcome of this consideration sets out the concerns of the WHC for the property, which need to be addressed, and responded to, in the monitoring programme going forward. Progress with the resolution of the WHC's specific concerns will be documented in the forthcoming State of Conservation reports.
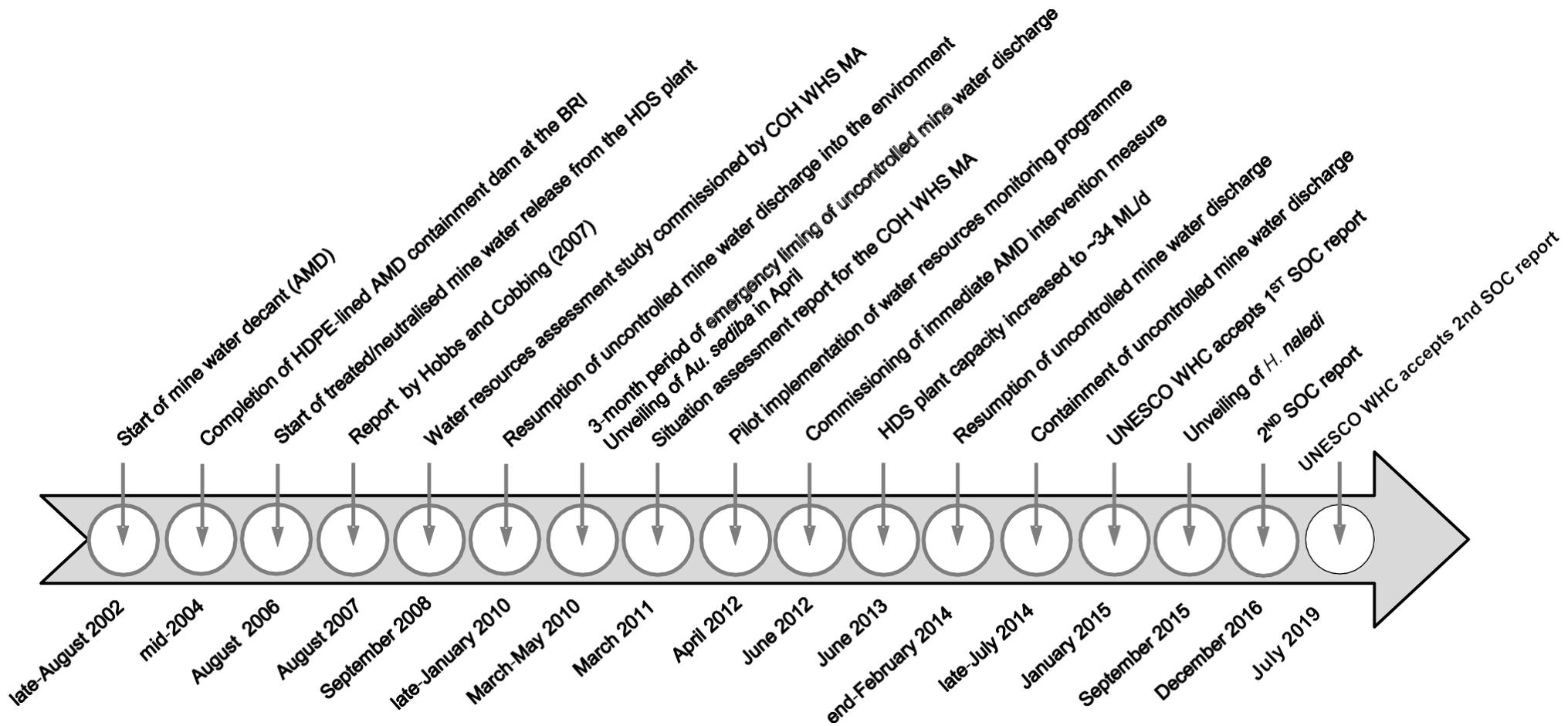
Figure 2   Timeline of key events relevant to the project and this report

3   RAINFALL

3.1   Quantity

The monthly precipitation data covering the period from October 2008 to September 2024, observed at the Sibanye-Stillwater (SS) rainfall station HDS within the mine vicinity, and station SC positioned approximately 13 kilometres (km) northward at the Sterkfontein Cave (**Figure 1**) is presented in **Figure 3**. The monthly rainfall for the dry season at station HDS totalled 110 millimetre (mm) yet no rainfall was measured for station SC during the same period. At HDS, the dry season rainfall decreased by approximately 29% from 2023 to 2024.

The 2024 wet season rainfall of 467 mm is among the lowest recorded at station HDS in the 16-year period from 2008 to 2024 (**Figure 4**). This amount is approximately 55% lower than the wet season rainfall measured in 2023 and ranks at the 7th percentile in the historical dataset, indicating it as one of the driest periods on record. Similarly, the 537 mm of wet season rainfall recorded at station SC ranks at the 42nd percentile, highlighting a moderately drier period for the region. Overall, the region experienced approximately 51% decrease in rainfall between 2023 and 2024.
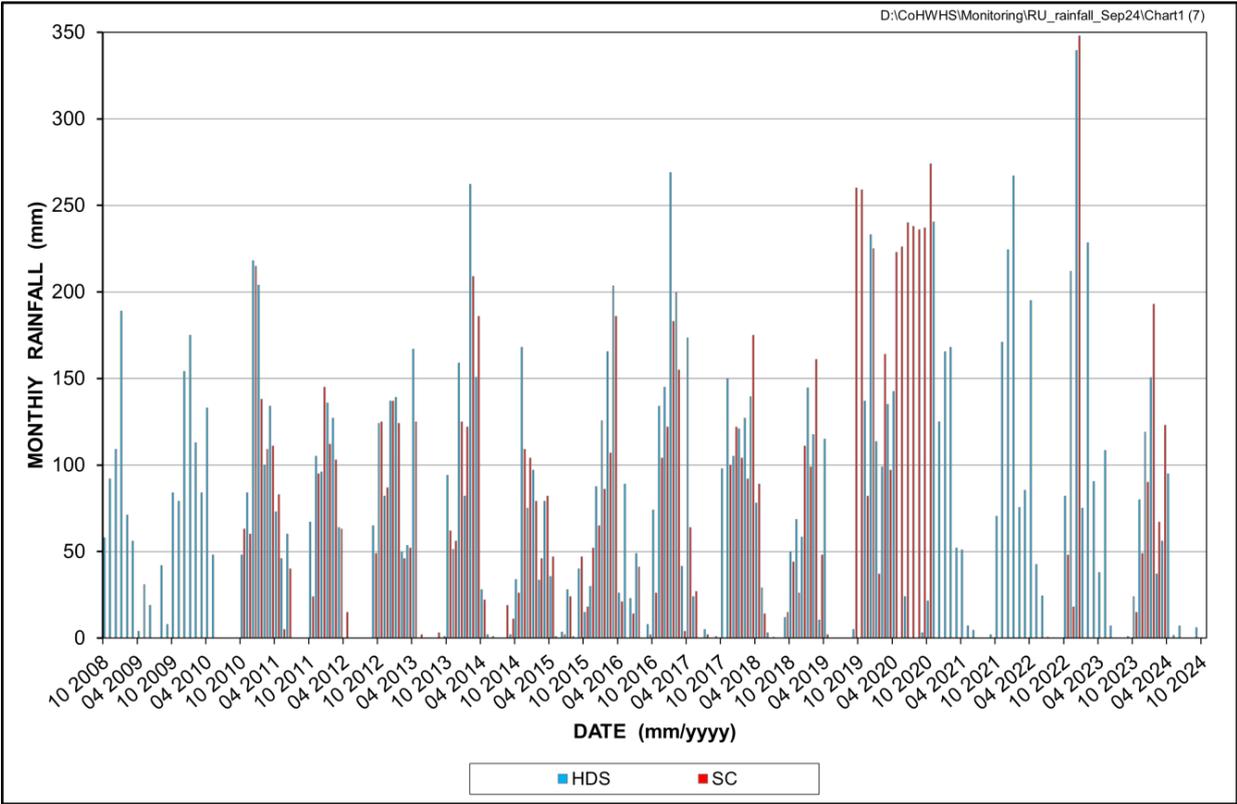
Figure 3   Monthly precipitation in the mine area (station HDS) from October 2008 to September 2024, and the concurrent record for the Sterkfontein Cave station from June 2010 to September 2024.
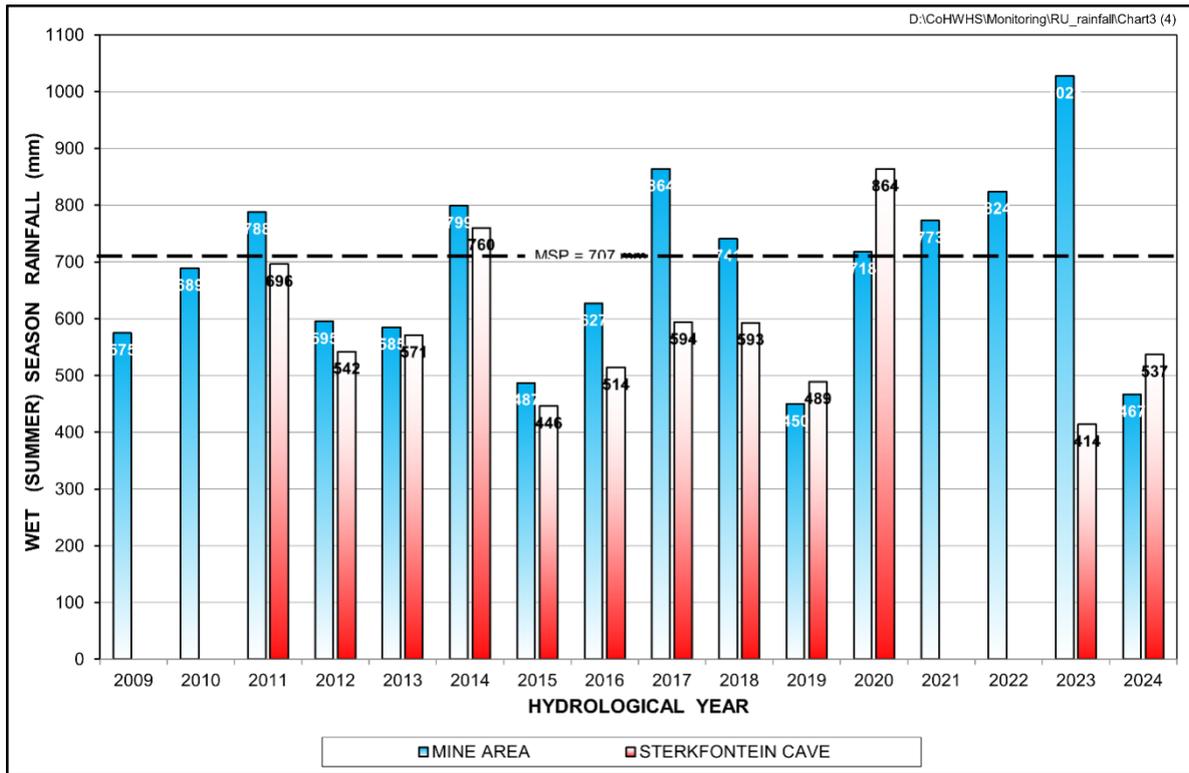
Figure 4   Total wet season (summer) rainfall in the mine area (HDS station) in the past fifteen hydrological years, also showing the comparison with that for the available contemporaneous Sterkfontein Cave record; MSP denotes mean summer precipitation.

3.2   Quality

The chemical composition of rainwater in the southwest region of the COHWHS property is assessed through samples collected from four rainfall stations managed by the Department of Water and Sanitation (DWS). These stations have a rainfall equivalent capacity of approximately 450 mm and are typically emptied every 2 to 4 months, depending on the season. Consequently, the chemistry of the collected rainwater represents a composite of multiple precipitation events over the collection period, which implies that the laboratory-determined pH values may not accurately reflect specific rainfall events.

No samples were collected beyond January 2024, and thus the water chemistry results from January 2024 are presented in **Table 1**, with the exception of station HDS, which includes data from the late dry season/early wet season as reported by Bugan *et al.* (2019). Efforts by the CSIR Project Team to acquire data for this site from either Sibanye-Stillwater or the DWS have been unsuccessful. The results from stations GP00303, GP00301, and SC pertain to late wet season/early dry season rainfall.

The observed rainwater chemistry at these monitoring stations consistently reaffirms the region's characteristic low salinity and predominantly acidic nature. However, the rainwater chemistry at the high-density sludge (HDS) station is relatively more saline than the other three stations. Due to insufficient data, the current understanding of temporal rainwater quality and distribution in the area cannot readily explain inter-station variances in sulphate, total alkalinity, and nitrate levels.

Table 1   Composite rainwater chemistry in the south-western portion of the property.

Variables	Unit	Rainfall Station			
		HDS[1]	GP00303[2]	GP00301[3]	SC[4]
Specific electrical conductance*	mS/m @ 25°C	18	3	2	2
pH*	$-\log_{10}\alpha_{H+}$	5.4	4.9	5.5	5.2
Calcium	mg Ca/L	6.7	0.6	0.5	0.5
Magnesium	mg Mg/L	1.4	<0.3	<0.3	<0.3
Sodium	mg Na/L	1.7	<0.6	<0.6	<0.6
Potassium	mg K/L	3.8	<0.6	<0.6	<0.6
Chloride	mg Cl/L	<2.0	<2.0	<2.0	<2.0
Sulphate	mg SO$_4$/L	32	5.9	5.4	5.1
Total alkalinity	mg CaCO$_3$/L	2.6	1.4	2.7	1.7
Nitrate + nitrite	mg N/L	11	0.71	0.63	0.42

*   Laboratory values
[1]   At the high-density sludge plant in the mine area (Bugan *et al.*, 2019)
[2]   At monitoring borehole GP00303, Vlakplaats 160IQ, Tarlton (sampled 15 January 2024)
[3]   At monitoring borehole GP00301, Sterkfontein 173IQ (sampled 15 January 2024)
[4]   At Sterkfontein Cave (sampled 15 January 2024)

4   SURFACE WATER HYDROLOGY

4.1   Physical Hydrology

4.1.1   Surface Water Discharge

The discharge of the Bloubankspruit system is monitored at the DWS gauging station A2H049, strategically located approximately 700 meters (m) upstream from the system's confluence with the Crocodile River (**Figure 1**). The extensive 52-year observed discharge record from 1972 to 2024 for this catchment (Quaternary A21D) provides the historical monthly statistics reported in **Table 2**. This record is updated as frequently as possible when new data are obtained from the station and processed by the DWS. As previously reported by Mvandaba and Mbuyi (2024), data collection at the station has faced multiple interruptions between June 2018 and March 2024 attributed to the national lockdown period and financial constraints that impeded regular data collection, updates, and essential maintenance of the data collection platforms during specific periods. The latest updated data record encompasses information from April 2024 through to mid-July 2024.

The historical total annual discharge, measured in cubic millimeters (Mm³), for complete hydrological years (ah) up to July 2024 is shown in **Figure 5**. Notably, the 2023 hydrological year (ah 2023) is the most recent complete year in the record. The hydrograph for the mean annual discharge reveals that the 2023 hydrological year recorded a discharge of approximately 77.5 Mm³, the highest discharge for the Bloubankspruit from October 1972 to September 2023. This significant discharge aligns with the occurrence of flash floods in the region between November 2022 and March 2023, following intense rainfall events (Krugersdorp News, December 2022). Noting the missing data, the total rainfall for the ah 2024 has resulted in a discharge volume of ~26.3 Mm³ which is ~66% less than the discharge of the 2023 hydrological year.

Table 2   Statistical analysis of Bloubankspruit monthly discharge data (Mm3/a) gauged at station A2H049 in the period October 1972 (a_h 1973) to July 2024 (a_h 2024) (latest data as at September 2024).

Variable	Month											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Count (n)	49	49	47	47	50	50	50	49	50	49	49	49
Minimum	0.682	0.268	0.711	0.721	0.706	0.828	0.886	0.847	0.521	0.939	0.890	0.770
5%ile	0.804	0.839	1.047	1.098	0.906	1.111	1.205	1.033	0.897	0.970	0.938	0.811
Mean	1.984	1.967	2.460	2.978	2.905	3.239	2.636	2.492	2.188	2.204	2.085	1.937
Median	1.720	1.800	2.212	2.526	2.385	2.624	2.205	2.082	1.852	1.945	1.969	1.628
95%ile	3.970	3.544	4.543	6.944	6.871	8.922	5.599	4.982	4.249	4.181	3.881	3.682
Maximum	4.211	4.577	7.199	13.007	10.619	11.351	7.007	5.708	6.427	5.031	4.897	4.773
SD	0.949	0.904	1.299	2.393	2.087	2.313	1.413	1.296	1.160	1.011	0.958	0.965
CoV (%)	48	46	53	80	72	71	54	52	53	46	46	50

- *All units are Mm^3 unless otherwise indicated.*
- *Analysis excludes months with missing and station rating exceedance data, but includes unaudited (recent) and estimated data*
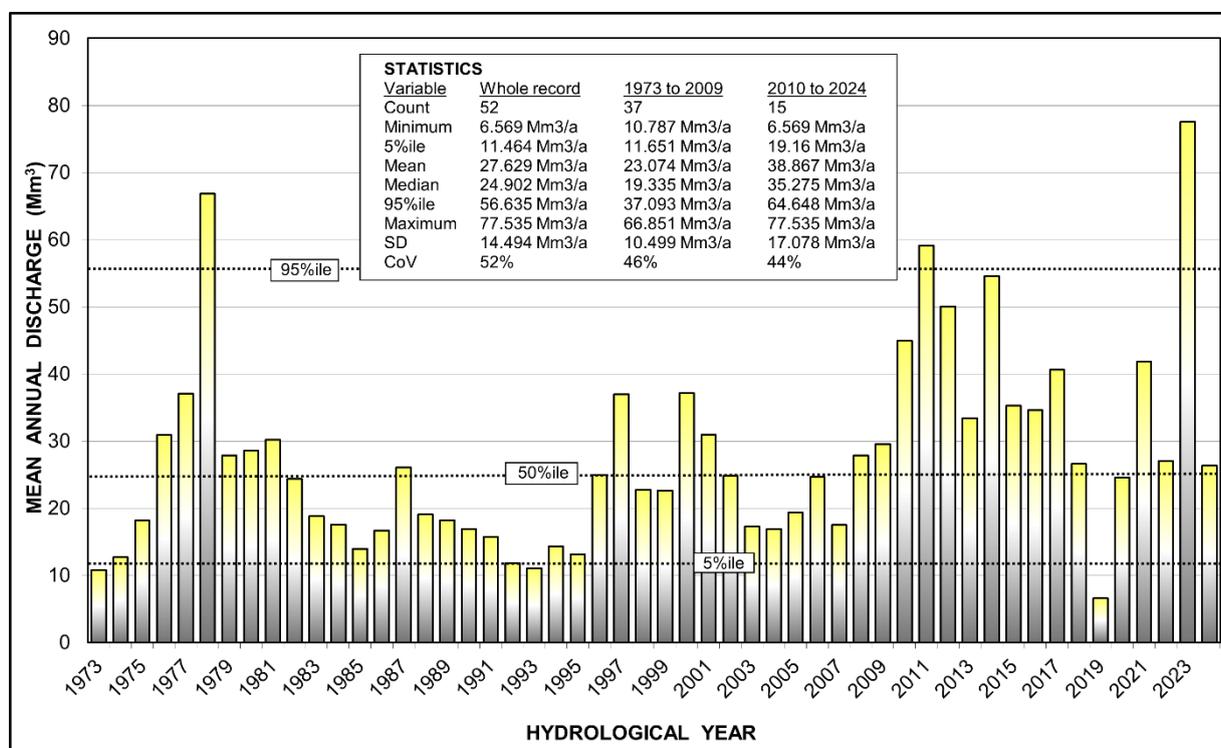
Figure 5   Graph of Bloubankspruit annual discharge gauged at station A2H049 for the period October 1972 (a_h 1973) to July 2024 (a_h 2024).

Figure 6 displays the average monthly instantaneous flow pattern at station A2H049 from October 1972 to July 2024. The highest mean monthly instantaneous discharge during this period, from October 1972 to July 2024, is 4.9 cubic metres per second (m³/s). This flood peak corresponds to the mean monthly discharge of the Bloubankspruit in January 2023. The highest mean monthly instantaneous discharge recorded between April 2024 and September 2024 is 1.5 m³/s however, this period has missing data for the August and September months. Comparably, the highest mean monthly instantaneous discharge recorded for the same period during the a_h 2023 i.e. April 2023 to September 2023, was 2.6 m³/s, indicating a ~41% decrease in the average monthly flow rate between the 2023 and 2024 dry season.

Despite the apparent lower flow rates for the a_h 2024, the trendline for the average monthly flow rate exhibits a general upward trajectory over the 52-year dataset, suggesting several probable hydrological scenarios in the COHWHS:

- Increased rainfall: Increased rainfall during the wet season may be contributing to a higher average monthly flow;
- Hydrological changes: Broader hydrological changes in the watershed or catchment area may be occurring, potentially due to climate change or other environmental factors.
- Increased discharge: The trendline may indicate the contribution of allogenic sources, including treated/neutralized mine water from the Western Basin, with a secondary contribution from municipal wastewater effluent from the Percy Stewart Wastewater Treatment Works as well as contributions from dams or reservoirs, leading to an increase in water release or discharge.
- Potential changes in land use: Changes in land use, such as urbanization or deforestation, could lead to increased runoff entering the water system, thus elevating flow rates.
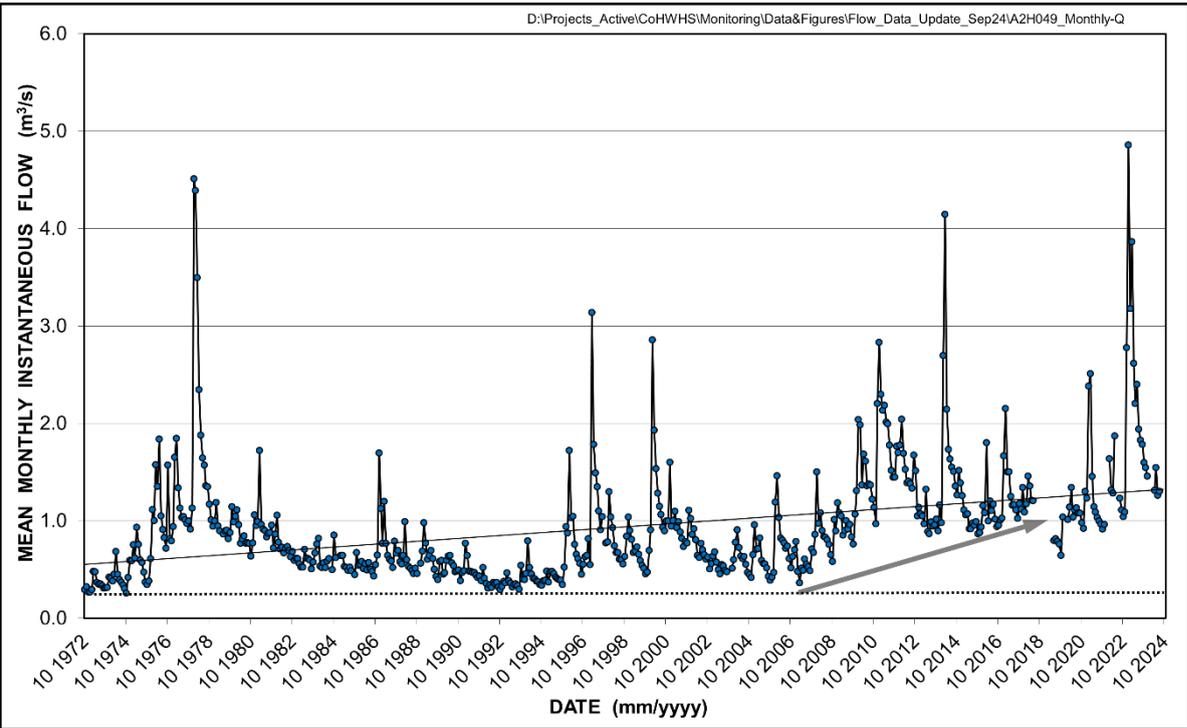
Figure 6   Long-term monthly hydrograph of the Bloubankspruit at station A2H049 for the period October 1972 to July 2024 (latest data as of September 2024).

4.1.2   *Surface Water Fluxes*

The extent of surface water loss, primarily to the karst aquifer, is determined by calculating the difference in measured streamflow discharge at two key stations: PF, which is situated at a culvert ~250 m downstream of F11S12 (Brickworks Dam) on the property Pinocchio's Farm and through which the lower-end of Tweelopiespruit flows, and MRd, located approximately 3.9 km downstream along the Rietspruit (**Figure 8**).

The latest data captured in September 2024 shows surface flow fluxes between the Pinocchio's Farm gauging site and MRd of magnitude 4.5 ML/d, respectively. This calculated flux is below the 5th percentile of the 15-year period from September 2009 to September 2024 (**Figure 7**), categorising it as one of the lowest observed during this timeframe. The volume of surface flow flux measured in September 2024 is ~55% less than the 10.1 ML/d flux calculated in March 2024 indicating a notable reduction in surface water discharge of the Tweelopiespruit/ Rietspruit systems.
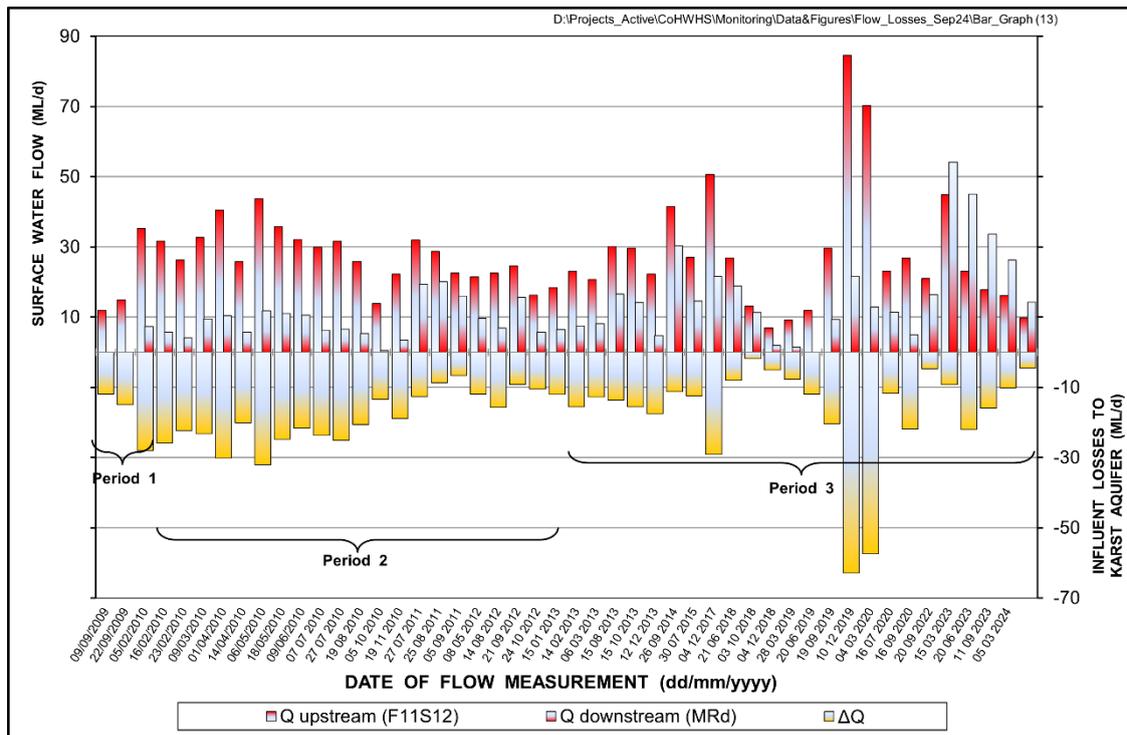
Figure 7   Graph of streamflow and influent losses to the karst aquifer in the lower Riet Spruit valley.

4.2   Chemical Hydrology

4.2.1   Mine Water Impact

4.2.1.1   Tweelopiespruit / Riet Spruit

From the point where it leaves the mine property down to its confluence with the Riet Spruit at Glen Almond north of the Krugersdorp Game Reserve (KGR), a distance of approximately 6.6 km, the chemistry of surface water in the Tweelopiespruit is still being monitored by Sibanye-Stillwater on a weekly basis at five localities (**Figure 8**). The monitoring of the variables pH, electrical conductivity (EC) and sulphate (SO_4) dates to May 2004. The results for two of these stations, namely the (upstream) Hippo and (downstream) Brickworks (F11S12) dams, are presented in **Figure 9** (pH), **Figure 10** (SEC), **Figure 11** (SO_4), **Figure 12** (Fe), Error! Reference source not found. (Mn) and **Figure 14** (U).

The patterns revealed in **Figure 9** to **Figure 14** reflect the temporal variation and trend in the respective variable values in surface water as it flows through the KGR. The period(s) of most severe and sustained mine water impact have previously been discussed in Hobbs (2014b). Of relevance to the period covered by this report is the recovery of the mine water treatment and management measures to 'operationally optimal' levels (period E in the Figures). This follows the excursion in the 2017 summer of mine water discharges to poorer (suboptimal) levels because of copious decant volumes. Mvandaba and Moloi (2024) have previously discussed the trend of each respective parameter from October 2023 to March 2024. Therefore, this report will focus on the emerging trends from March 2024 to September 2024:

- The pattern of the pH values (**Figure 9)** recorded at the Hippo and Brickworks (F11S12) dams illustrate a gradual increasing trend, ranging from 7.4 to 8.5 and 4.3 to 6.6, respectively. The most common pH value recorded for the Brickworks Dam is 4.7, indicating that the water at this location is predominantly sub-acidic year-round. Through consultations with the DWS (communications with Mtetwa and Ntanta, Nov. 2024), it is understood that the treated mine water discharged upstream of the Hippo Dam into the Tweelopiespruit is circum-neutral, with pH values ranging from 6.5 to 9.5. The discharge also has relatively elevated concentrations of salinity and sulphate, although these are within the directive limits. In contrast, consistently sub-acidic pH values (ranging from 4.0 to 6.2) were observed downstream at the Brickworks (F11S12) dam and at the sampling site on Pinocchio's Farm (Mvandaba and Moloi, 2024). This suggests an apparent degradation in surface water quality from the point of discharge to the downstream locations. Further investigation is needed to determine the underlying cause of this change.

- The SEC values (**Figure 10**) at both stations show a gradually decreasing trend, with concentrations oscillating between 300 mS/m and 341 mS/m for the Hippo Dam and 260 mS/m and 300 mS/m for the Brickworks (F11S12) Dam.

- Sulphate concentrations (**Figure 11**) appear to be stable at both stations, with values averaging 2027 mg/L at the Hippo Dam and 1714 mg/L at the Brickworks (F11S12) Dam.

- The iron concentration (**Figure 12**) at the Hippo Dam station indicates marginally increasing levels with a range of 0.003 mg/L to 0.4 mg/L. At Brickworks (F11S12) Dam, the iron concentration illustrates apparent stable values which oscillate mostly between from 0.003 mg/L to 0.05 mg/L.

- Manganese concentrations (Error! Reference source not found.) at both the Hippo and Brickworks (F11S12) Dams display a decreasing trend, averaging 0.5 mg/L and 1.1 mg/L, respectively.
- At both stations, uranium (**Figure 14**) has maintained a consistent concentration of 0.02 mg/l beyond March 2020.

A statistical analysis of the data associated with each of the periods of record A–B, B–C, C–D, D–E and E– defined by the divisions recognised in **Figure 9** to **Figure 14** is presented in **Table 3**. Period F in **Table 3**

provides a more recent look at the statistics between October 2020 and September 2024, but may be considered to generally show the continuation of the recovery of mine water treatment and management measures in the Western Basin. The outcome of the statistical analysis offers a quantitative assessment of the specific differences in variables between different periods at each station and across various stations. The effectiveness of these measures is reflected in the median and 95th percentile values during the E–F and F- periods, which, in most cases, exhibit the lowest values across the five periods of analysis. This trend is comparable to the C-D period, which corresponds to the implementation of immediate Acid Mine Drainage (AMD) intervention measures.

At the Hippo Dam station, the parameters recorded in September 2024 remain lower than the values recorded during the C-D period (**Table 4**).

However, at the Brickworks (F11S12) Dam the median pH value of 5.5 coupled with the mode pH value of 4.7 for the March 2024 to September 2024 period indicate prevailing acidic conditions for the site and suggest possible episodic discharge of mine water.
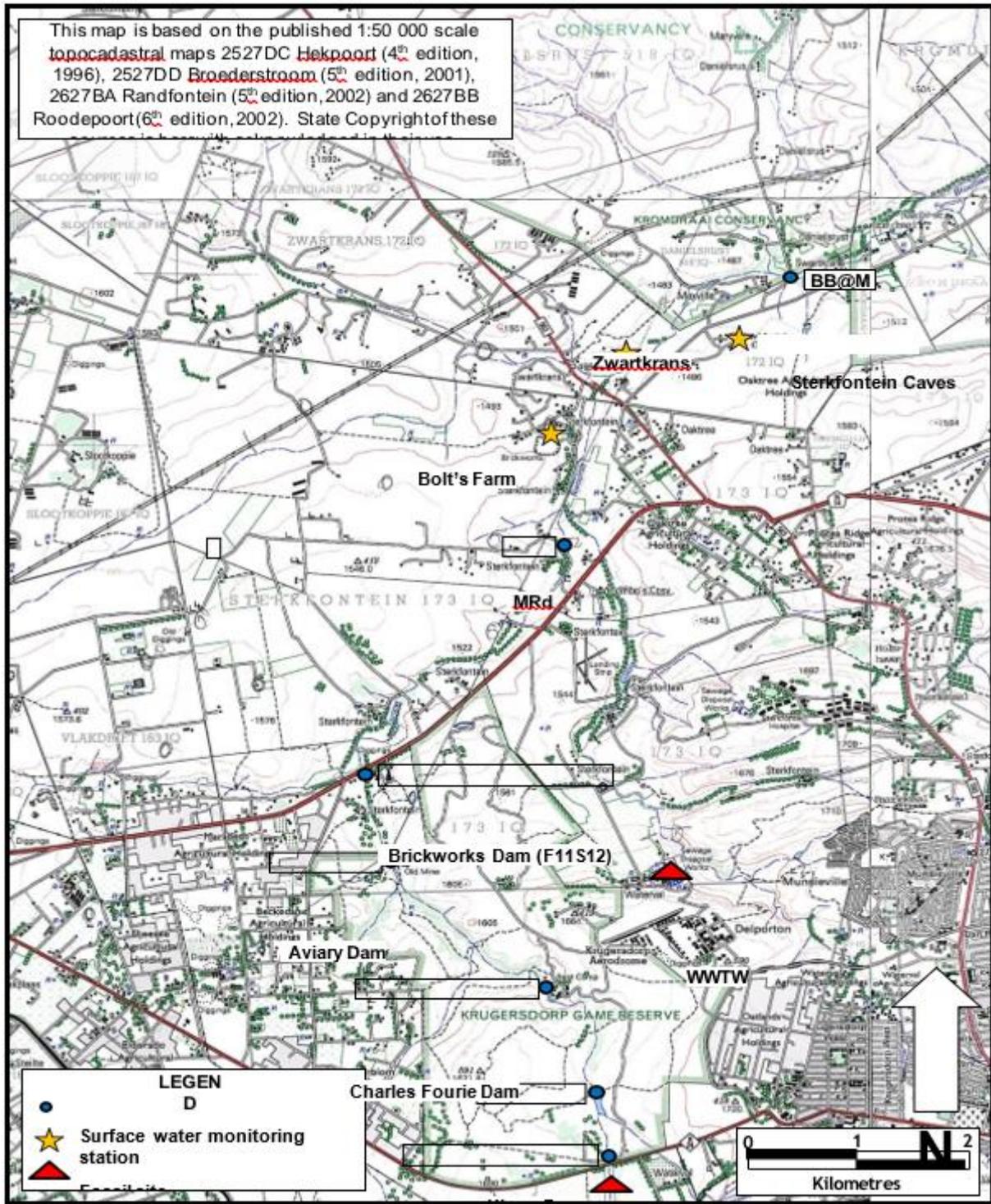
Figure 8   Locality map of surface water quantity and quality monitoring stations.

4.2.1.2   Bloubankspruit

The latest available analysis of hydrochemical data from station A2H049 is as captured in the April 2023 to March 2024 edition of the *Status Quo* report (Mvandaba and Moloi, 2024). The DWS has reported an inability to update the data, citing system access issues caused by limited data connection, instrument failure as well as cost-cutting measures which reduced the frequency of data collection at the station (Botes, March 2024). The comprehensive analysis of synoptic surface water chemistry data for the DWS flow

gauging station A2H049 (**Table 4**) at the lower reach of the Bloubankspruit system, as detailed in earlier reports, has been revised to highlight significant temporal variations in specific variable values. Noteworthy gaps existed in the dataset between May 2018 and July 2022 due to the absence of data collection activities at the site. The DWS attributed this hiatus to financial constraints and instrument failures.

The recent data update, spanning the timeframe from July 2022 to November 2022, provides a more current perspective, filling the gaps in the dataset. This update ensures a more recent portrayal of the surface water chemistry dynamics, allowing for a nuanced understanding of the current variable-specific changes.

Table 4 reflects statistics for a 'pre-impact' period, August 2002 to January 2010, and a 'post-impact' period February 2010 to May 2018, and July 2022 to November 2022. Barring sulphate concentrations at the 95th percentile (during the July 2022 to November 2022 period), none of the variables reported for either the 'pre-impact' or the 'post-impact' periods exceed the respective SANS (2015a; 2015b) health-related limits for potable water, where specified, even at the C5 (95%ile) level and, in the case of pH, also at the C95 (5%ile) level.
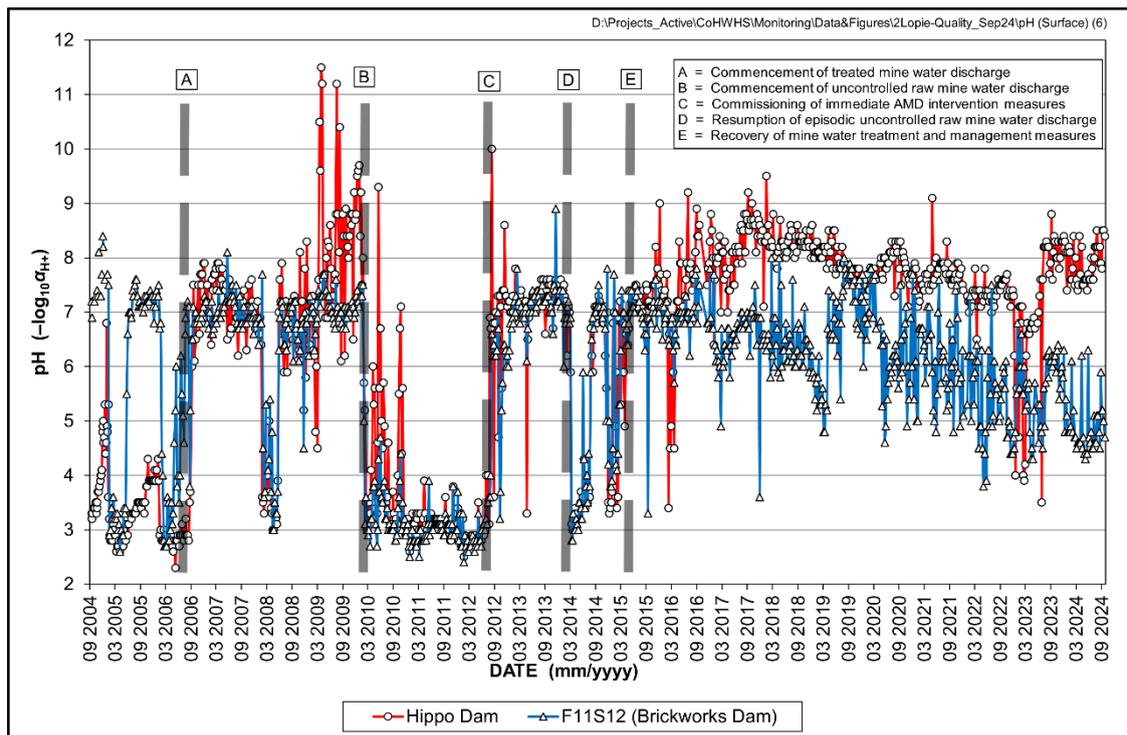
Figure 9   pH pattern of Tweelopiespruit surface water in the period September 2004 to September 2024.
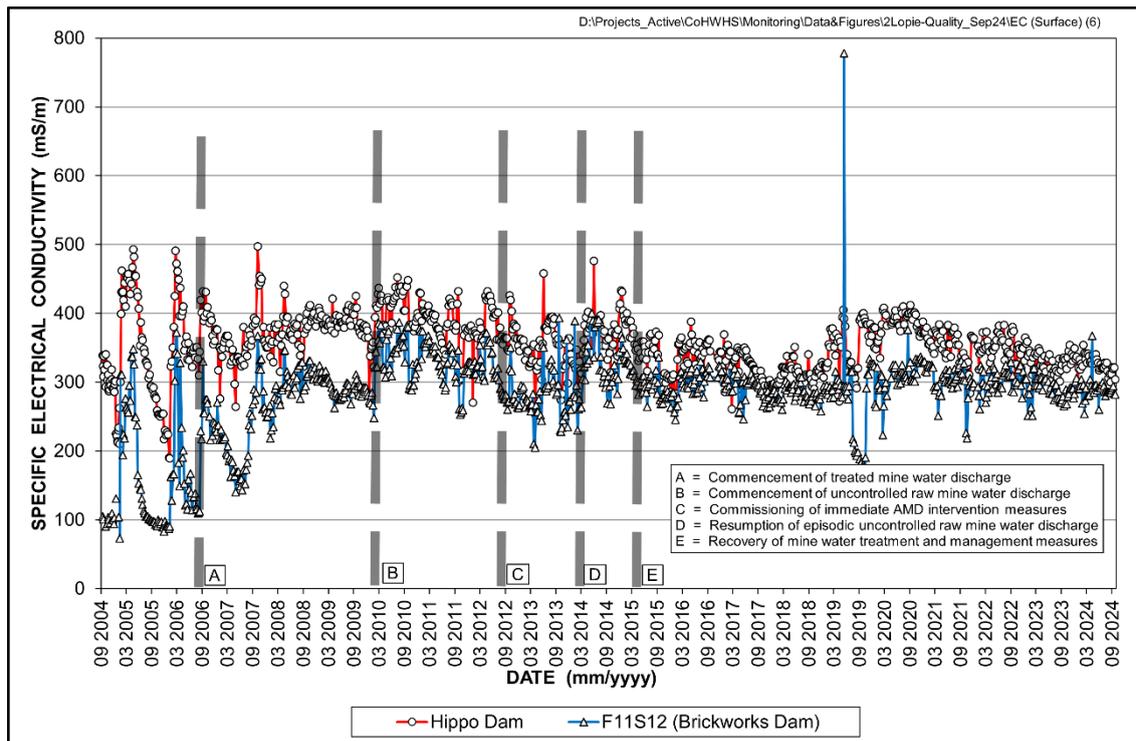
Figure 10 Specific electrical conductivity pattern of Tweelopiespruit surface water in the period September 2004 to September 2024.
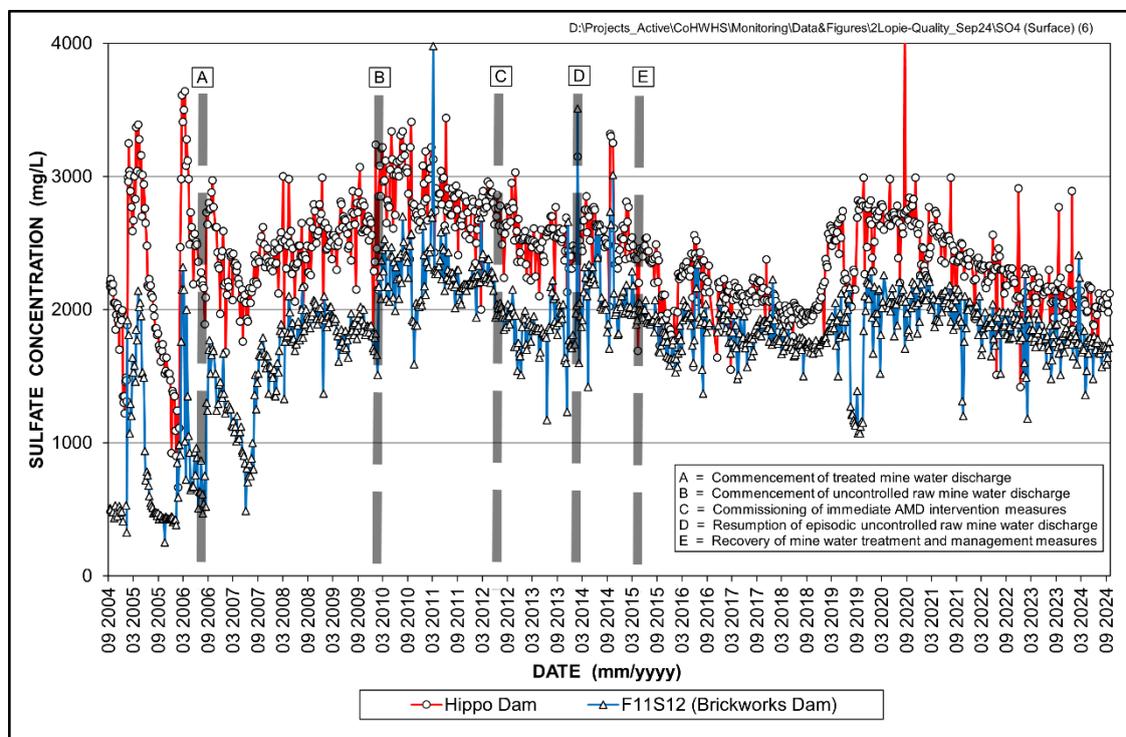
Figure 11 Sulphate pattern of Tweelopiespruit surface water in the period September 2004 to September 2024.
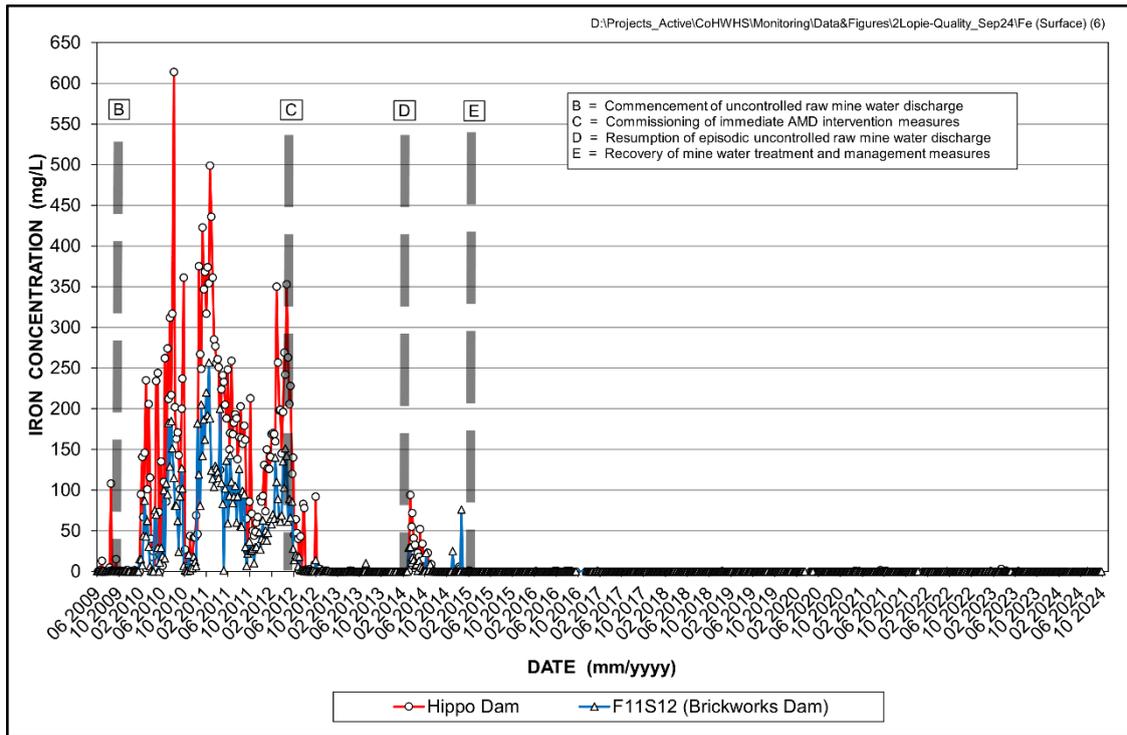
Figure 12   Iron pattern of Tweelopiespruit surface water in the period June 2009 to September 2024.
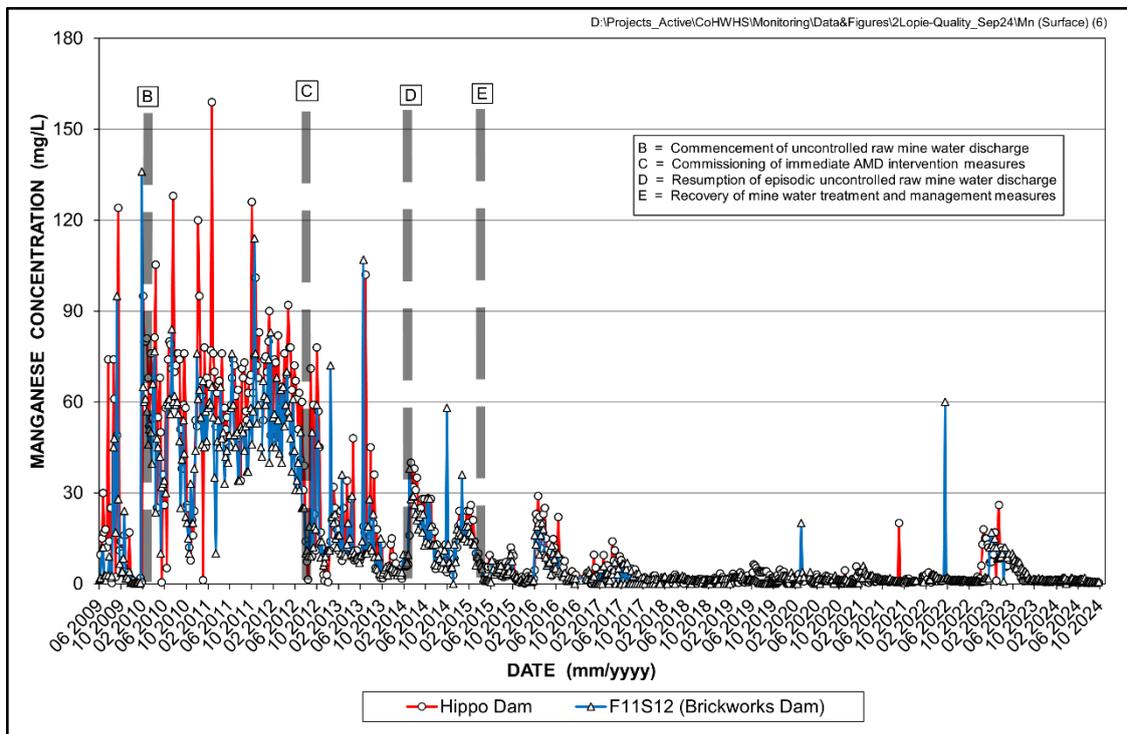
Figure 13   Manganese pattern in Tweelopiespruit surface water in the period June 2009 to September 2024.
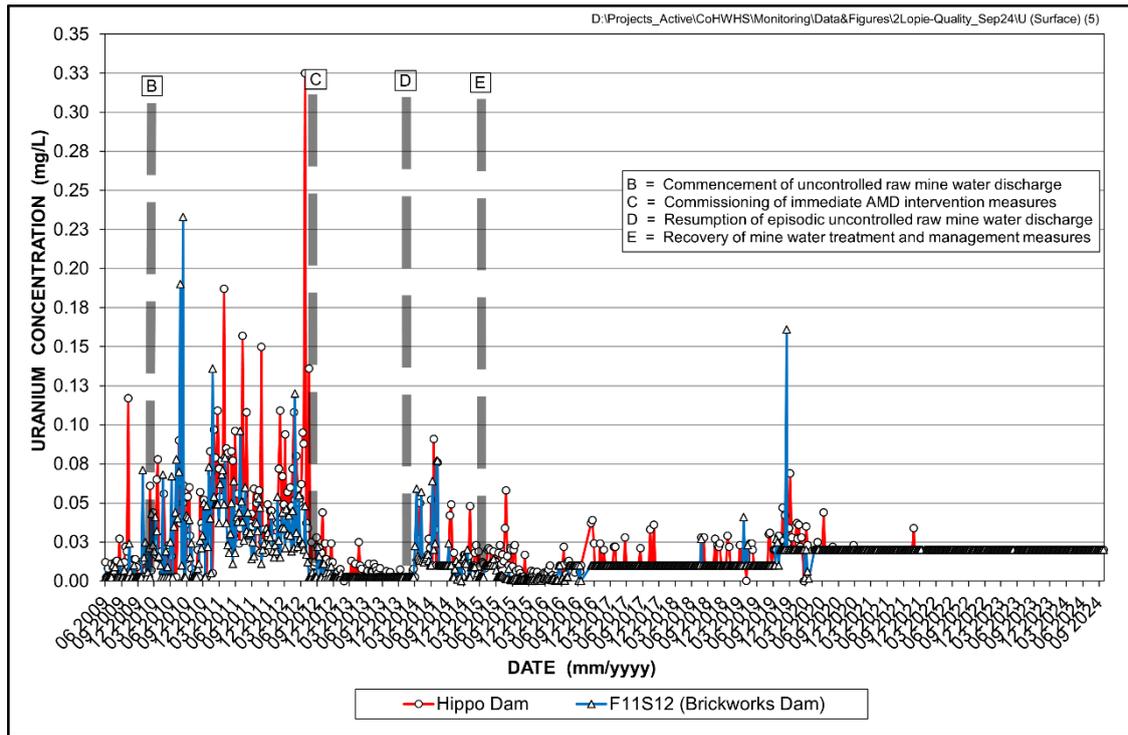
Figure 14   Uranium pattern in Tweelopiespruit surface water in the period June 2009 to September 2024.

Table 3 Summary statistics of period-related surface water chemistry variability in the Tweelopiespruit (latest data as at September 2024).

Variable	Statistical Parameter	Hippo Dam						F11S12 (Brickworks Dam)					
		A—B(1)	B—C(2)	C—D(3)	D—E(4)	E—F(5)	F— (6)	A—B(1)	B—C(2)	C—D(3)	D—E(4)	E—F(5)	F— (6)
pH (−log10αH+)	n	176	129	83	57	2 69	212	173	128	83	57	276	203
	5%ile	3.6	2.8	5.9	3.2	6.8	6.6	3.9	2.7	5.3	3.0	5.4	4.4
	Mean	—	—	—	—	—	—	—	—	—	—	—	—
	Median	7.2	3.2	7.2	4.9	7.9	7.6	6.9	3.0	7.0	5.0	6.7	5.5
	95%ile	9.3	5.7	7.6	7.1	8.7	8.3	7.4	3.9	7.4	7.4	7.7	6.9
	SD	1.5	1.0	0.8	1.6	0.7	0.8	0.9	0.4	0.9	1.7	0.7	0.8
	CoV (%)	22.0	30	11	32	9.0	10.5	14	14	13	32	10	14.8
SEC (mS/m)	n	175	129	83	57	269	212	172	128	83	57	276	203
	Mean	374	391	350	376	348.7	345	268	332	281	329	291	296
	Median	379	393	354	377	347.5	342	283	330	276	323	293	295
	95%ile	426	438	395	417	393.9	389	329	378	350	391	323	325
	SD	32	33	34	28	24.2	24	48	29	34	34	41	19
	CoV (%)	9	8	10	7	7	7	18	9	12	10	14	7
SO4 (mg/L)	n	176	128	82	56	269	212	171	128	83	56	276	203
	Mean	2448	2846	2520	2585	2305.4	1876	1636	2264	1879	2137	1832	1856
	Median	2460	2815	2525	2541	2300.0	2266	1760	2240	1870	2075	1840	1850
	95%ile	2828	3220	2770	2950	2770.0	2240	2015	2593	2148	2640	2160	2140
	SD	262	226	193	231	304.3	2759	349	245	268	274	222	192
	CoV (%)	11	8	8	9	13	301	21	11	14	13	12	10
Fe (mg/L)	n	33	129	83	57	242	208	33	128	82	57	230	202
	Mean	4.7	168.4	2.5	8.9	0.0	0.1	0.3	72.9	0.47	4.9	0.0	0.03
	Median	0.4	163.0	0.03	0.10	0.0	0.0	0.2	64.0	0.08	0.04	0.0	0.02
	95%ile	13.8	365.2	3.1	52.6	0.0	0.3	0.8	186.3	1.00	25.7	0.1	0.10
	SD	18.8	116.2	13.10	19.5	0.0	0.3	0.3	57.7	1.9	12.2	0.0	0.05
	CoV (%)	399	69	528	220	5.3	341	94	79	407	2518	115	148
Mn (mg/L)	n	34	129	83	57	249	208	33	128	83	57	231	169
	Mean	18.1	62.7	16.5	17.3	3.8	2.4	10.3	50.3	14.4	16.1	3.0	2.9
	Median	9.8	65.0	11.0	16.0	2.2	1.0	2.7	50.0	10.0	14.0	1.8	1.3
	95%ile	74.0	95.0	56.1	32.6	11.9	12	46.2	76.0	45.0	30.4	9.8	10.0
	SD	27.6	23.5	18.0	9.1	4.6	3.9	19.4	17.6	15.8	9.9	3.6	5.4
	CoV (%)	153	38	109	53	120	161	188	35	110	61	117	184.5

(1) 09/2006 – 01/2010 (2) 02/2010 – 07/2012 (3) 08/2012 – 02/2014 (4) 03/2014 – 03/2015 (5) 04/2015 – 09/2020 (6) 10/2020 – 09/2024

Table 4   Synoptic overview of Bloubankspruit water chemistry at station A2H049 in the periods August 2002 to January 2010 and February 2010 to May 2018 and July 2022 to November 2022 (latest data as of March 2024).

Variable	Statistical Parameter																					SANS (2015a)(1)
	Period August 2002 to January 2010							Period February 2010 to May 2018							Period July 2022 to November 2022							
	n	5%ile	Mean	Median	95%ile	SD	CoV (%)	n	5%ile	Mean	Median	95%ile	SD	CoV (%)	n	5%ile	Mean	Median	95%ile	SD	CoV (%)	
pH (−log10αH+)	251	7.7	—	8.1	8.4	0.2	2	202	7.5	8.2	8.2	8.5	0.3	3.7	5	7.0	7.2	7.2	7.3	0.1	1.7	5.0–9.7
SEC (mS/m)	232	51.1	61.2	62.3	66.8	5	8	199	61.5	93.4	90.1	126	23.2	24.8	5	81.5	81.5	124.1	137.7	26.3	32.3	<170
TDS (mg/L)	137	347.6	438.5	448.9	479.3	41.5	9	134	474.7	695.8	674.9	980.1	171.9	24.7	5	570.9	875.5	898.8	1153.8	250.6	28.6	<1200
Ca (mg/L)	172	40.1	51.3	52.1	57.7	5.31	10	191	54.3	96.3	90.7	153.7	33	34.3	5	47.9	147.0	152.2	281.5	105.2	71.6	n.s.
Mg (mg/L)	171	23.3	30.2	30.4	34.9	4.8	16	192	28.4	44.2	42.8	59.7	10.6	24	5	72.1	149.9	180.3	212.0	66.3	44.3	n.s.
Na (mg/L)	185	19.1	27.5	27.7	34	4.7	17	166	28.3	41.7	40.5	58.4	10.1	24.3	5	21.7	48.5	57.4	59.3	19.5	40.2	<200
K (mg/L)	173	1.4	2.4	2.4	3.4	0.7	27	169	2.9	4.1	4	5.7	1	24.4	5	5.5	5.8	5.8	6.3	0.3	5.8	n.s.
Cl (mg/L)	175	29.2	36.2	36.3	43.5	4.8	13	198	31.3	38.8	38.5	45.3	5.3	13.6	5	29.2	40.8	0.1	45.3	8.6	21.0	<300
SO4 (mg/L)	191	63.4	85.8	83.9	110	15.1	18	189	96.8	284	247.8	475	132.7	46.7	5	290.2	398.3	412.3	501.4	91.2	22.9	<500
HCO3 (mg/L)	185	146.1	188.1	190.2	216.1	21.1	11	189	242.4	422.2	404.4	621.6	121.6	28.8	5	0.0	134.7	142.9	159.0	32.0	23.8	n.s.
NO3+NO2 (mg N/L)	214	3.294	4.74	4.414	7.085	1.19	25	193	3.5	5.6	5.4	8.3	1.6	27.7	5	2.6	5.8	5.6	8.8	2.8	47.6	<11
PO4 (mg P/L)	247	0.043	0.189	0.158	0.451	0.131	69	197	0.005	0.097	0.048	0.261	0.124	127.8	5	0.262	0.524	0.400	0.925	0.300	57.3	n.s.
Si (mg/L)	247	4.93	5.84	5.83	6.69	0.6	10	198	4.95	5.64	5.6	6.59	0.61	10.86	5	4.7	5.6	5.7	6.3	0.7	12.8	n.s.
Fe (mg/L)	69	0.006	0.035	0.014	0.12	0.056	163	61	0.004	0.019	0.012	0.072	0.024	126.3	4	0.000	0.019	0.021	0.025	0.007	36.1	<2
Mn (mg/L)	69	0.001	0.049	0.002	0.146	0.226	459	61	0.001	0.162	0.003	0.05	0.855	527.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.5
Al (mg/L)	65	0.001	0.06	0.014	0.091	0.262	437	60	0.003	0.019	0.009	0.057	0.026	136.8	4	0.007	0.030	0.016	0.071	0.034	115.5	<0.3

(1)   Standard health-related limit for consumption of 2 L/d over 70 years by a 60 kg person

4.2.2   Municipal Wastewater Impact

The most recent results (September 2024) from hydrochemical and microbiological analyses of water samples collected by the CSIR along the Blougatspruit (both upstream and downstream of the Percy Stewart WWTW) and Bloubankspruit are summarised in **Table 5.** Unlike the acidic nature of the Tweelopiespruit and Rietspruit surface water, the hydrochemistry of the Blougatspruit and Bloubankspruit is characterised by relatively greater alkalinity, evidenced by higher bicarbonate values and pH values which consistently range between 7.2 to 7.9. The moderately alkaline surface water reflects the continuing neutralising capacity of the carbonate strata and the impact of the municipal wastewater from the local WWTW.

The Blougatspruit is the conduit for the municipal wastewater effluent into the COHWHS property. The reticence of local government to provide water quality data for wastewater released to the Blougatspruit from the municipal wastewater treatment works (WWTW) has been documented previously (e.g. Hobbs, 2016a; 2016b; 2017a). Water samples collected ~5 km upstream (i.e. PSU Spring and PSU) and ~ 1 km (PSD) and ~5 km downstream of the WWTW end-of-pipe (EoP) (i.e. BG@N14 and BB@M) provide a comparative measure of the bacteriological contamination in the Blougatspruit from this facility. This impact extends into the Bloubankspruit in its passage through the south-eastern portion of the property. The severity of the bacteriological contamination, more specifically of a faecal nature, is reflected in total coliform and *E. coli* values that routinely exceed a most probable number (MPN) count of 2419.6 per 100 mL at several sites along the Blougatspruit and Bloubankspruit, namely, BG@N14 and BB@M (**Table 5**). Furthermore, the CSIR project team has witnessed (**Figure 15**) and received several accounts of obnoxious odours, murky water foam, and raw sewerage, in the Blougatspruit and Bloubankspruit rivers from local residents and reported to the MA, however the exact point of emergence of the water pollution has not been verified.

The South African Water Quality Guidelines (DWAF, 1996) do not have an applicable target water quality range for coliform in aquatic ecosystems, however, the drinking water guidelines (SANS 241:1, 2015) stipulate less than 10 MPN/100 mL (<10 MPN/100 mL) for total coliforms and zero detection for E. coli. According to the World Health Organization (2011), a count of 1 – 10 MPN/100 mL is regarded as low risk; 11 – 100 MPN/100 mL is moderate risk while an E. coli count greater than 100 MPN/100 mL is adjudged high risk. *E.coli* counts greater than 1000 MPN/100 mL are considered to be extreme high risk. Given the bulk volume of raw sewerage noted in these rivers, the surface water in these systems can be regarded as extreme high risk and it can also be argued that the municipal wastewater poses an equally dire threat to the quality and subsequent fitness for use of receiving surface water resources as does mine water. This threat extends into the Crocodile River as main stem of the Bloubankspruit.

Table 5 Water chemistry and microbiological results of samples collected at monitoring sites along the Blougatspruit and Bloubankspruit between March 2024 and September 2024.

Variable	PSU Spring (Blougatspruit)			PSU (Blougatspruit)			PSD (Blougatspruit)			BB @ N14 (Blougatspruit)			BB @ M (Blougatspruit)			BB@NOE (Blougatspruit)			SANS (2015a)(1)
	Mar 24	Jun 24	Sep 24	Mar 24	Jun 24	Sep 24	Mar 24	Jun 24	Sep 24	Mar 24	Jun 24	Sep 24	Mar 24	Jun 24	Sep 24	Mar 24	Jun 24	Sep 24	
pH ($-\log_{10}\alpha H+$)	6.3	6.1	6.4	7.9	7.9	7.8	7.5	7.6	7.8	7.5	7.6	7.5	7.6	7.4	7.3	7.9	7.2	7.5	5.0–9.7
SEC (mS/m)	62	56	58	31	34	35	78	88	136	72	82	110	170	180	195	124	128	144	<170
Ca (mg/L)	9.2	8	8.2	25	24	22	33	21	33	34	21	32	210	231	247	149	155	159	n.s.
Mg (mg/L)	7.5	6.5	6.5	11	11	11	11	12	12	11	11	11	56	55	55	56	55	55	n.s.
Na (mg/L)	98	89	88	21	22	26	60	90	166	57	83	105	79	94	102	54	60	74	<200
K (mg/L)	0.6	<0.6	0.6	3.5	3.3	3.6	14	13	16	11	12	14	9.4	9.9	11	5.3	5.4	5.8	n.s.
Cl (mg/L)	129	109	110	22	26	28	79	69	193	68	64	98	57	60	76	41	43	63	<300
SO4 (mg/L)	41	40	40	28	32	32	52	57	83	47	50	94	702	779	802	460	493	490	<500
HCO3 (mg/L)	10	8	8.8	83	72	81	214	243	297	196	234	323	148	153	163	185	125	193	n.s.
NO3+NO2 (mg N/L)	11	11	11	2.5	5.4	4	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.18	<0.05	0.27	0.36	9.2	0.33	<11
Si (mg/L)	4.4	4.1	4.1	4.6	3.3	3.4	5.7	5	5.4	5.5	4.5	7.6	5.4	4.8	4.6	5.8	5.4	5.5	n.s.
Fe (mg/L)	0.03	0.03	0.04	0.3	0.2	0.14	5.3	2.5	2.1	3.3	1.8	2	1.3	0.83	1.1	0.47	0.35	0.74	<2
Mn (mg/L)	0.09	0.02	0.02	0.07	0.06	0.03	0.44	0.23	0.2	0.71	0.35	0.67	0.47	0.47	0.54	0.66	0.25	0.48	<0.5
Al (mg/L)	<0.02	<0.02	0.04	<0.02	0.02	0.05	0.5	0.45	0.81	3.3	0.27	0.47	1.3	0.16	0.31	0.09	0.08	0.18	<0.3
Total coliform bacteria (MPN/100 mL)	1413.6	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	<10
E. coli (MPN/100 mL)	3.1	17.5	9.7	>2419.6	1413.6	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6	686.7	>2419.6	>2419.6	n.d.

Figure 15 Water quality degradation as observed along the Blougatspruit and Bloubankspruit during the September 2024 monitoring run. Signs of contamination, including murky water, foam, and sludge buildup, were noted ~1 km downstream of the Percy Stewart WWTW (A), near the N14 bridge (B), near the Makiti Restaurant on Sterkfontein Caves road (C), and near the weir that is ~500 m downstream of Kromdraai Spring.

4.3   Salt Load

The latest available analysis of hydrochemical data from station A2H049 is as captured in the April 2023 to September 2023 edition of the Status Quo report (Mvandaba and Shadung, 2023). The DWS has since reported an inability to update the data, citing data connection issues, instrument failure as well as cost-cutting measures which reduced the frequency of data collection at the station (Botes, March 2024).

The six years gap of missing data between May 2018 and July 2022 presents a challenge with comprehensively interpreting the long-term monthly trend in the TDS load delivered by the Bloubankspruit (**Figure 16)**. However, the statistics presented indicate an increasing salt load since early-2007. The text box in **Figure 16** lists the median and 95%ile values associated with different periods of record. The period February 2010 to July 2012 reveals a significant increase in the median and 95%ile values. This is readily attributable to the very high salt loads experienced in the 2011 hydrological year. Similar conditions prevailed in the subsequent period (August 2012 to March 2018) as indicated in **Figure 16** (text box). An evaluation of the sub-regional and regional temporal salt loads delivered to Hartbeespoort Dam is presented by Hobbs (2017c).

Similarly, the long-term monthly trend in the SO_4 load delivered by the Bloubankspruit (**Figure 17**) mimics the TDS load pattern (**Figure 17**) in the period since early-2010. The most recent period (August 2012 to September 2023) exhibits a lower median value of 1925 (tons per month) t/m compared to the 2053 t/m of the preceding period (February 2010 to July 2012). These circumstances indicate that the most recent period experienced lower sulphate loads than previously**. Figure 18** and **Figure 19** reflect more recent SO_4**:** TDS ratio values in the range 41 to 52%.
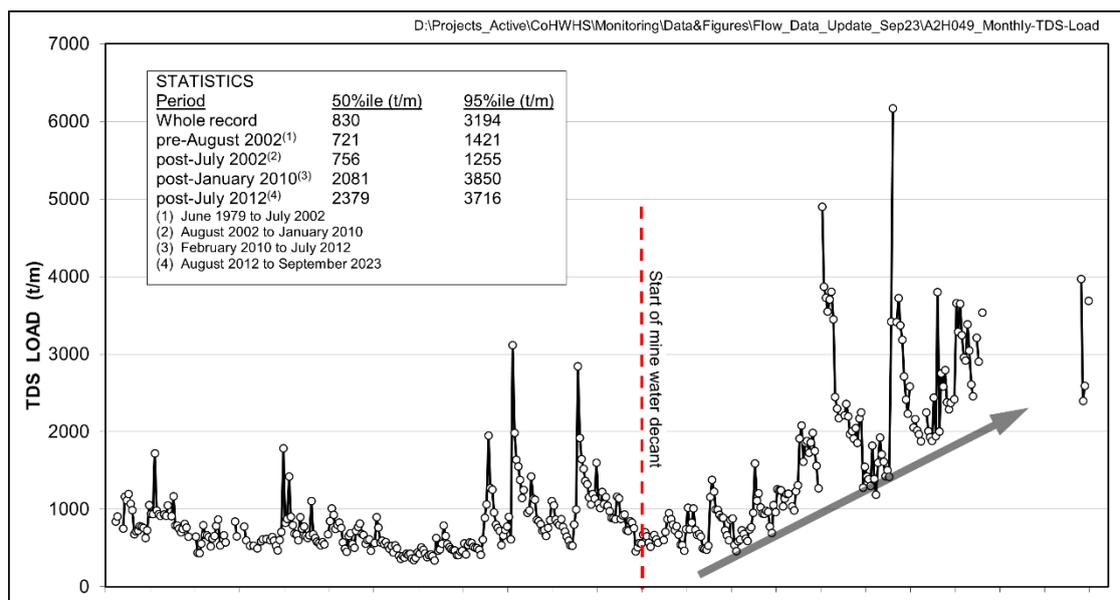
Figure 16   Long-term (June 1979 to September 2023) monthly TDS load pattern and trend in the Bloubankspruit at station A2H049.
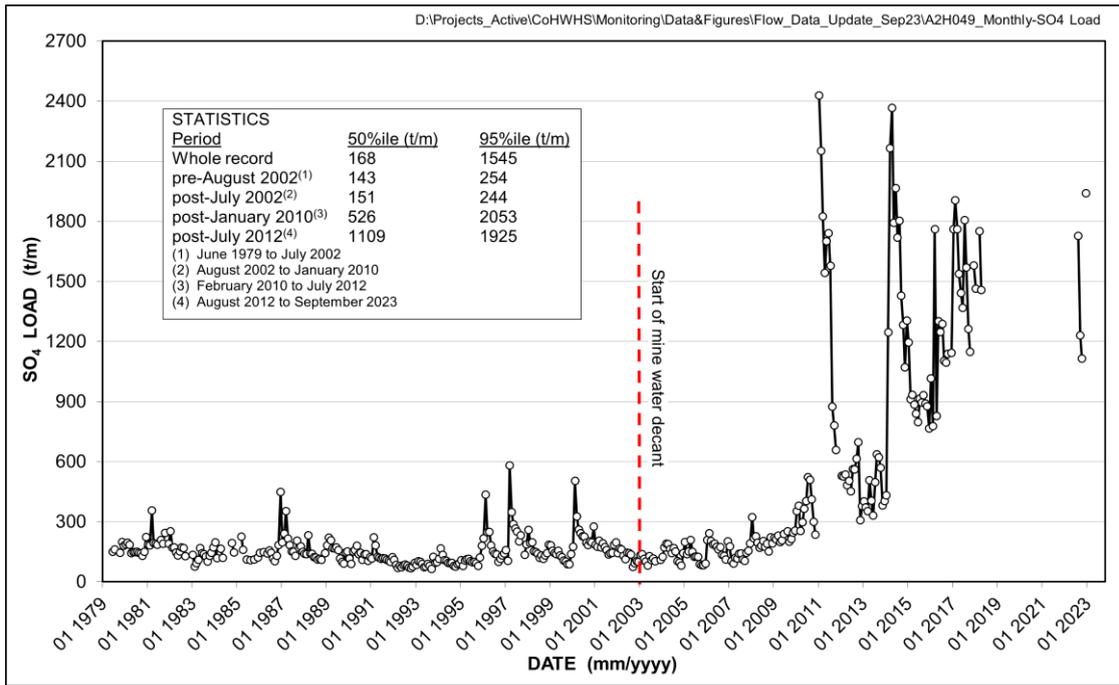
Figure 17 Long-term (June 1979 to September 2023) monthly SO4 load pattern and trend in the Bloubankspruit at station A2H049.
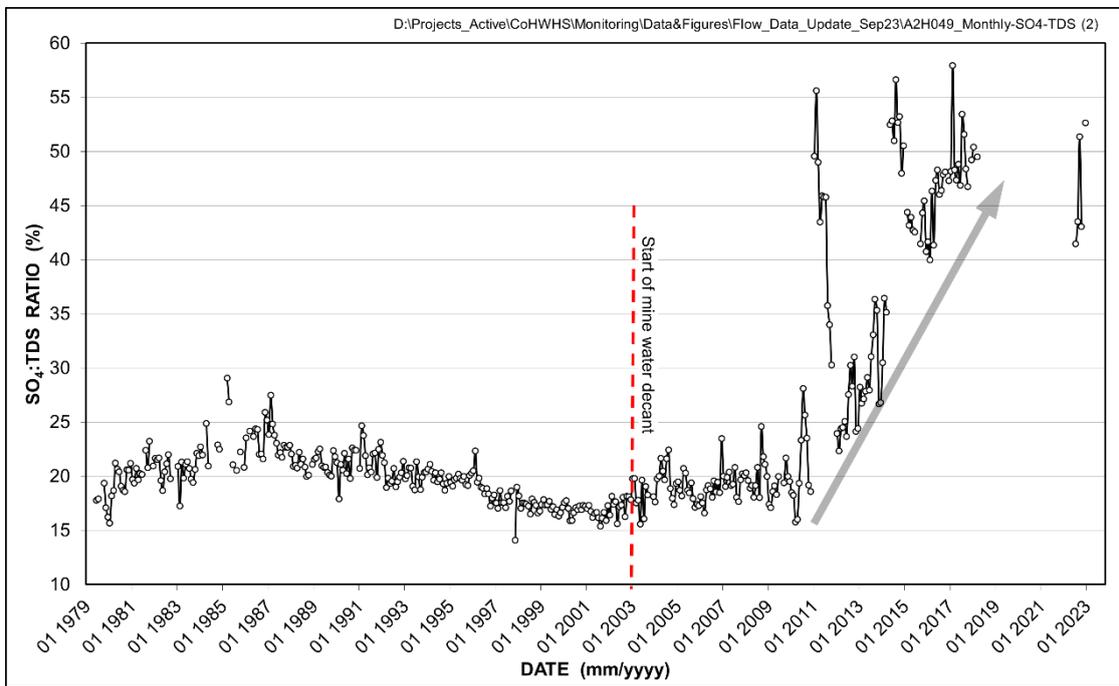
Figure 18 Long-term (June 1979 to March 2018) trend in the SO4: TDS ratio at station A2H049.

23

Figure 19   Pattern and trend of the SO_4: TDS ratio at station A2H049 since the start of mine water decant in the Western Basin in mid-2002.
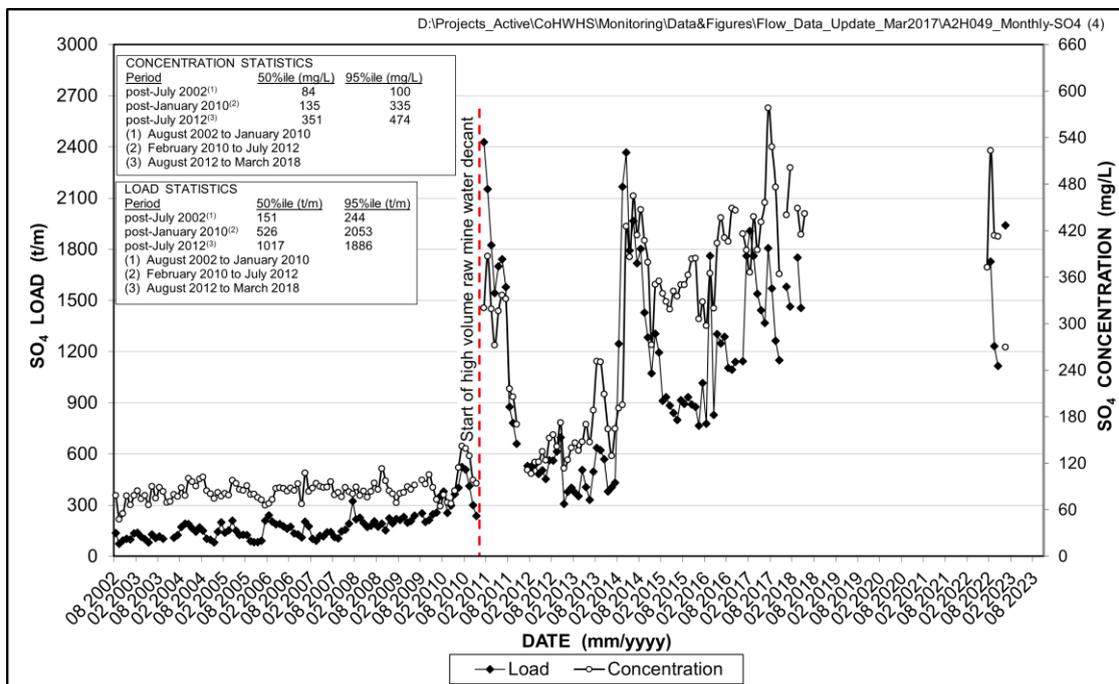
Figure 20   Monthly SO_4 concentration and load pattern and trend in the Bloubankspruit at station A2H049 since mid-2002.

5 GROUNDWATER HYDROLOGY

5.1 Physical Hydrogeology

5.1.1 Monitoring Framework

An inspection of the more recent potentiometric response in DWS monitoring boreholes located downstream of the mine area is presented in **Figure 21.** The boreholes are grouped into southern, central and northern segments to distinguish between their relative locations in the downstream receiving hydrogeologic environment. This distinction is brought out by using absolute groundwater level elevations that describe a decrease from south to north both within and between the respective segments. The most recent data presented in this report corresponds to monitoring conducted in September 2024.

5.1.2 Sub-regional Groundwater levels

The groundwater hydrographs shown in **Figure 21** illustrate a slight decrease in the groundwater level elevations in the northern and central segments between March 2024 and September 2024. Barring the marked decrease in the groundwater level for station GP00308, the groundwater elevations in the southern segment display relatively stable values.
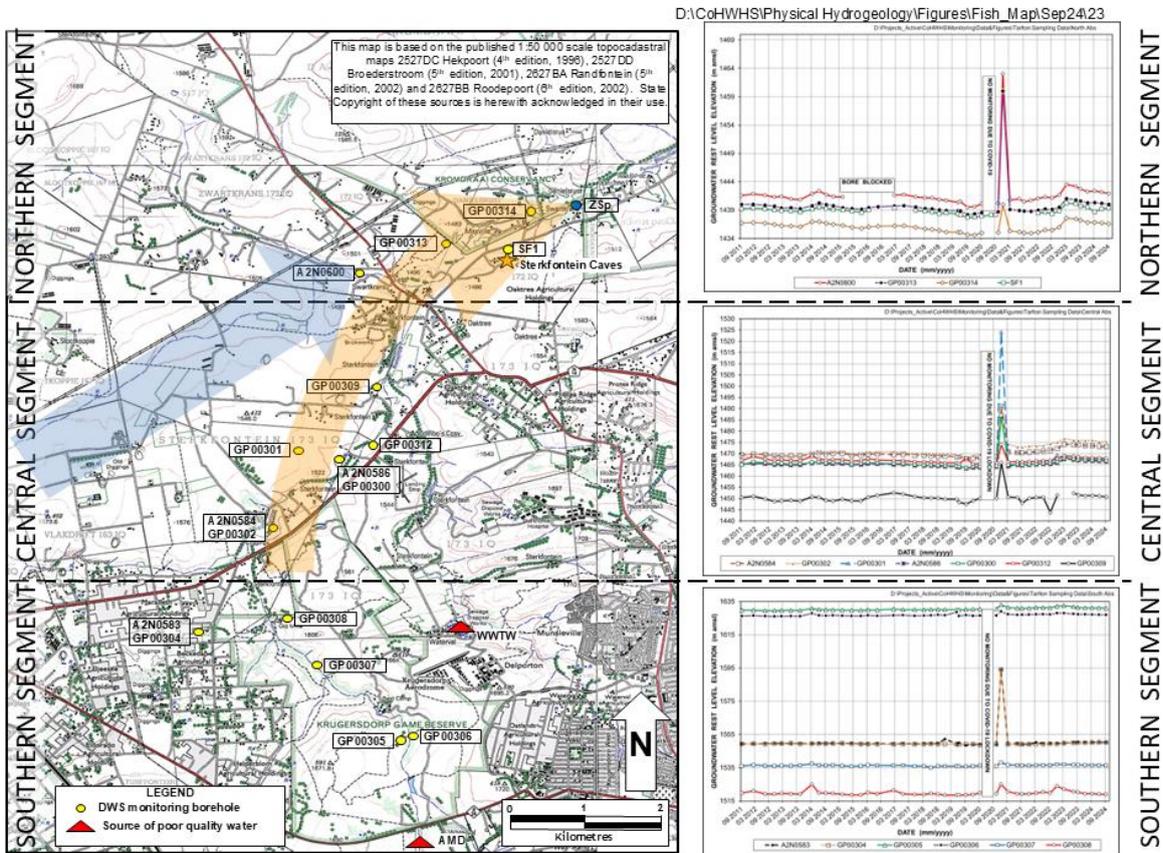
Figure 21   Distribution of DWS monitoring boreholes with groundwater hydrographs (right); brown arrow denotes principal direction of impacted groundwater flow, and blue arrow direction of natural karst groundwater flow.

5.1.3 Sterkfontein Cave Groundwater Level

The response of the water level of the Sterkfontein Cave lake to changes in rainfall patterns and surface water discharge over the last 19 years is visually represented in Error! Reference source not found.**.** The hydrograph depicts fluctuations since mid-2010, totalling approximately 1 metre, with elevations varying within the range of 1439 ± 0.5 meters above mean sea level (amsl). Hobbs *et al.* (2018) hypothesize that the cave lake will remain at its current level in the future, sustained by elevated discharge rates from the upper tributaries of the Bloubankspruit, specifically the Tweelopies/Rietspruit system and the Blougatspruit. These tributaries facilitate allogenic groundwater recharge into the Zwartkrans Basin, primarily from mine water and municipal wastewater.

The red data point in Error! Reference source not found. indicates the groundwater elevation in September 2024 at 1439.4 m amsl, showing a notable increase of 0.65 m since March 2024. This rise contrasts with the observed decline in groundwater levels in the central and northern sections of the COHWHS property, as depicted in **Figure 21.** As a result, further trend monitoring is necessary to investigate the cause of this discrepancy.
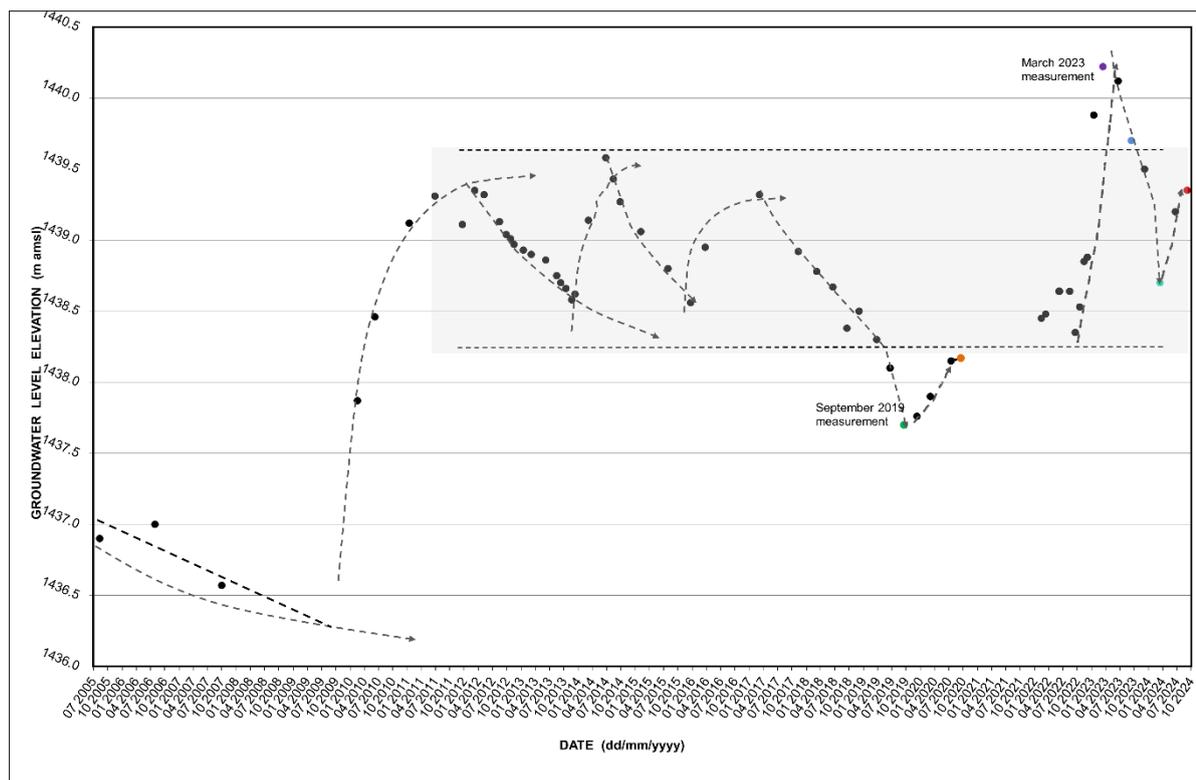
Figure 22 Groundwater level response pattern and trend in borehole SF1 that serves as a proxy for the lake water level in Sterkfontein Cave; blue-green and red data points respectively represent March 2 and September 2024 groundwater level and the shaded area.

Figure 23   The groundwater level of the Sterkfontein cave lake as observed in September 2024.

5.1.4   Discharge from the Dolomitic Springs

Every six months, the discharge from the dolomitic springs in the COHWHS is measured, specifically targeting the end of the wet (March/April) and dry (September/October) seasons. This bi-annual measurement schedule aims to analyse variations in spring contributions to river flow, expand the limited spring discharge database, and identify any future impacts. Since March 2019, flow has been measured at eight of the ten identified springs (**Table 6**). The 'measured discharge' represents measurements taken upstream and downstream of the spring's source, with 'spring discharge' calculated from the difference between these two values.

In some locations, such as the Tweefontein and Nash springs, only a portion of the stream's width is gauged due to the lack of suitable cross-sectional areas, necessitating an appropriate uncertainty factor. For this report, discharge measurements from March 2024 and September 2024 are compared (**Table 6**):

- Consistent with previous reports, the highest producing springs are the Zwartkrans, Noulip and Nash springs with apparent discharges of 21.06 ML/d, 8.44 ML/d and 10.29 ML/d, respectively.

- In September 2024, the Nouklip and Nash springs exhibited discharge rates approximately 50% and 27% lower, respectively, compared to March 2024. This decrease in discharge aligns with the expected seasonal variation between the wet and dry seasons.

There is however a level of uncertainty in these measurements due to continuous and direct extraction at the springs' sources and turbulence over rocky streambeds. The specific responses of these springs to rainfall and discharge variations within the COHWHS property have not been precisely quantified. A comprehensive analysis considering all factors affecting channel transmission losses, such as water usage and evapotranspiration rates, is necessary for a more precise understanding of the springs' behaviour and improved management strategies.

Figure 24   Various scenes of clear spring water in the COHWHS: groundwater emerging from the Zwartkrans Spring (A), streamflow generated by the Plover's Lake (B) and Nash (C) Springs and a recreational dam supplied by the Nouklip Spring.

Table 6   Dolomitic spring discharge measured in March 2024 and September 2024.

Spring	Compartment	Measured Discharge (Mar 23)		Spring Discharge (Mar 23)		Measured Discharge (Mar 24)		Spring Discharge (Mar 24)		Previous Discharge Volume [1]	
		(m³/s)	(ML/d)	(m³/s)	(ML/d)	(m³/s)	(ML/d)	(m³/s)	(ML/d)	(m³/s)	(ML/d)
Zwartkrans (upstream)	Zwartkrans	0.51	43.94	0.1	8.67	0.65	56.00	0.24	21.06	~0.1	~8.6
Zwartkrans (downstream)		0.61	52.61			0.89	77.06				
Plover's Lake	Krombank	0.046	3.96	0.046	3.96	0.034	2.95	0.034	2.95	~0.06	~5.2
Plover's Lake (culvert)											
Kromdraai (upstream)	Krombank	–	–	–	–	–	–	–	–	~0.28	~24.1
Kromdraai (downstream)		1.25	107.7			1.39	119.92				
Danielsrust	Danielsrust	0.05	4.1	0.05	4.1	0.024	2.046	0.024	2.046	~0.03	~2.4
Nouklip	Diepkloof	0.196	16.92	0.196	16.92	0.098	8.44	0.098	8.44	~0.14	~12.4
Tweefontein	Tweefontein	0.02	1.91	0.02	1.91	0.019	1.604	0.019	1.604		
Nash	Uitkomst	0.16	14.11	0.16	14.11	0.12	10.29	0.12	10.29		
Broederstroom	Broederstroom	0.03	2.4	0.03	2.4	0.32	3.37	0.32	3.37	~0.02	~1.8

[1] After Hobbs (2011)

5.2 Chemical Hydrogeology

5.2.1 DWS Monitoring Framework

The DWS groundwater monitoring programme in the south-western portion of the property was substantially expanded with the establishment of an additional 13 monitoring boreholes in late-2010. These stations (identified by the alpha-numeric code GP00###) supplement the four stations (identified by the alpha-numeric code A2N0###) that are the legacy of the mid-1980s DWAF study (Bredenkamp *et al.*, 1986) in the region. In 2022, the borehole near the Zwartkrans Spring (26.008220 S, 27.745 E) was added to the DWS monitoring programme as site A2N0811. The distribution of the monitoring network is shown in **Figure 25** and **Figure 26**. Whereas the older stations support a quasi-continuous monitoring record dating back to 2003, the record of the newer stations commences in March 2011. The outcome of this DWS groundwater monitoring programme (hereinafter referred to as simply 'the monitoring programme') forms the basis for evaluating the hydrochemical impact of mine water on the receiving karst environment (**Section 5.2.2**). The most recent chemical analyses of groundwater provided for the south-western portion of the property corresponds to monitoring conducted in June 2024 and September 2024.

5.2.2 Mine Water Impact

The magnitude of the mine water impact on the karst aquifer in the Zwartkrans Basin is illustrated in **Figure 25** and **Figure 26** with the aid of bar graphs for the chemical variables pH and SEC respectively. Spatially, the bar graphs in **Figure 25** reflect a general progressive decrease in pH, from south to north within the southern, central and northern segments. The pH trendlines at individual stations however show seasonal variability, albeit marginal. Recent pH values in the southern segment range between 6.1 to 8.8, and those in the central segment range from 6.7 to 8.8. In the northern segment, the most recent pH values are in the range 7.8 to 7.9. Due to the dissolution of carbonate rocks, the pH of karst groundwater is buffered and nearly neutral across all the groundwater sites.

The specific electrical conductivity (salinity) of groundwater sampled in the southern and central segments of the study area demonstrates a general progressive increase in salinity from south to north. In all instances, the recent individual salinity values are either similar to or slightly higher than earlier results. The proximity of the Tweelopiesruit and Rietspruit to these sites appears to impact groundwater salinity in these segments. However, in the northern segment, the spatial salinity trend along the flow path shows a decline, with a decreasing trend in salinity at each station, except for the Zwartkrans Spring. The recent (September 2024) salinity values are constrained to the ranges of 142 to 175 mS/m in the northern segment, 84 to 235 mS/m in the central segment, and 28 to 270 mS/m in the southern segment. The patterns described above reflect the north to north-easterly flow path followed by the allogenic recharge of mine water in the karst aquifer which is also described in **Figure 27**.

The extent of the mine water impact on the karst aquifer of the Zwartkrans Basin is shown in **Figure 27**, and provides an indication of the sulphate trend at each monitoring station in terms of increasing, stable or decreasing in the recent past, by comparing the sulphate concentration values of July 2016 to September 2024. Consistent with previous reports, the trendlines from March 2024 to September 2024 confirm the spatial variability of sulphate concentrations at individual stations. These trendlines illustrate that sulphate values at the north-eastern end of the study area are typically lower than those at sites closer to the mine locations. The seasonal variation suggests higher sulphate concentrations in water resources during the dry season compared to the wet season.
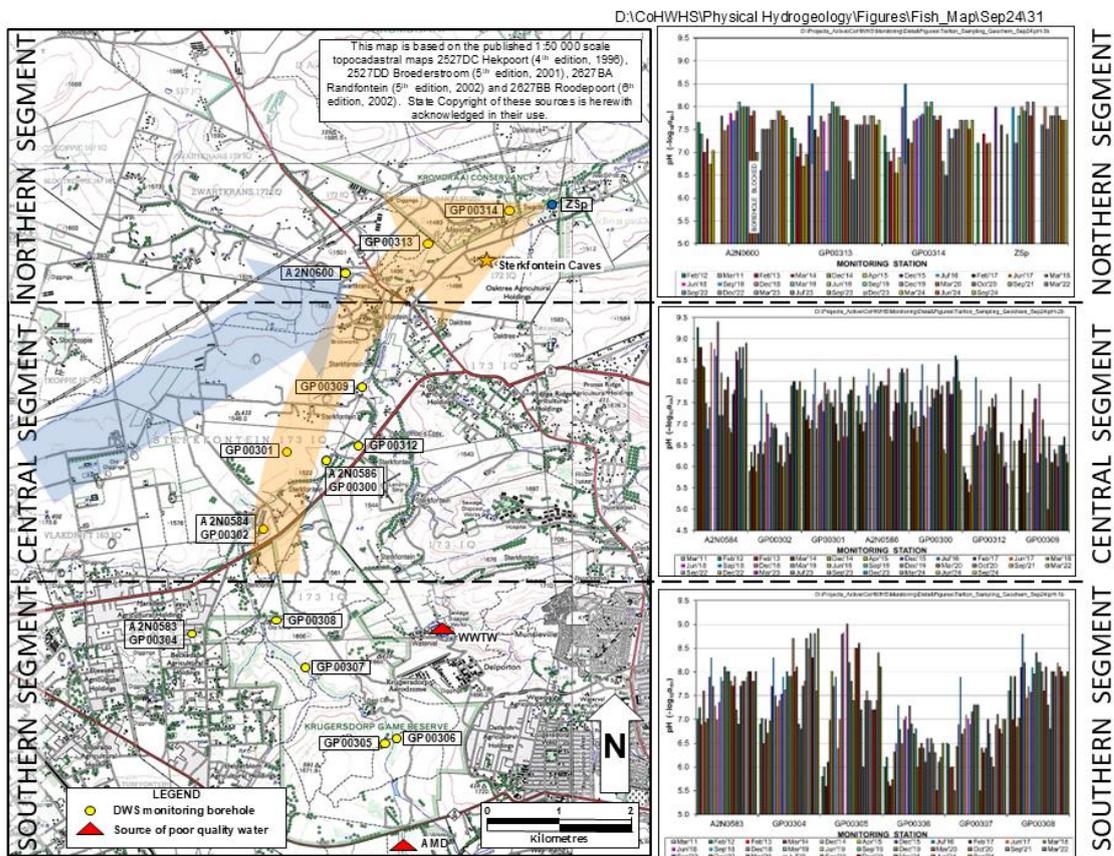
Figure 25   Distribution of DWS monitoring boreholes with pH pattern and trend as bar graphs; brown arrow denotes principal direction of impacted groundwater flow, and blue arrow direction of natural karst groundwater flow.
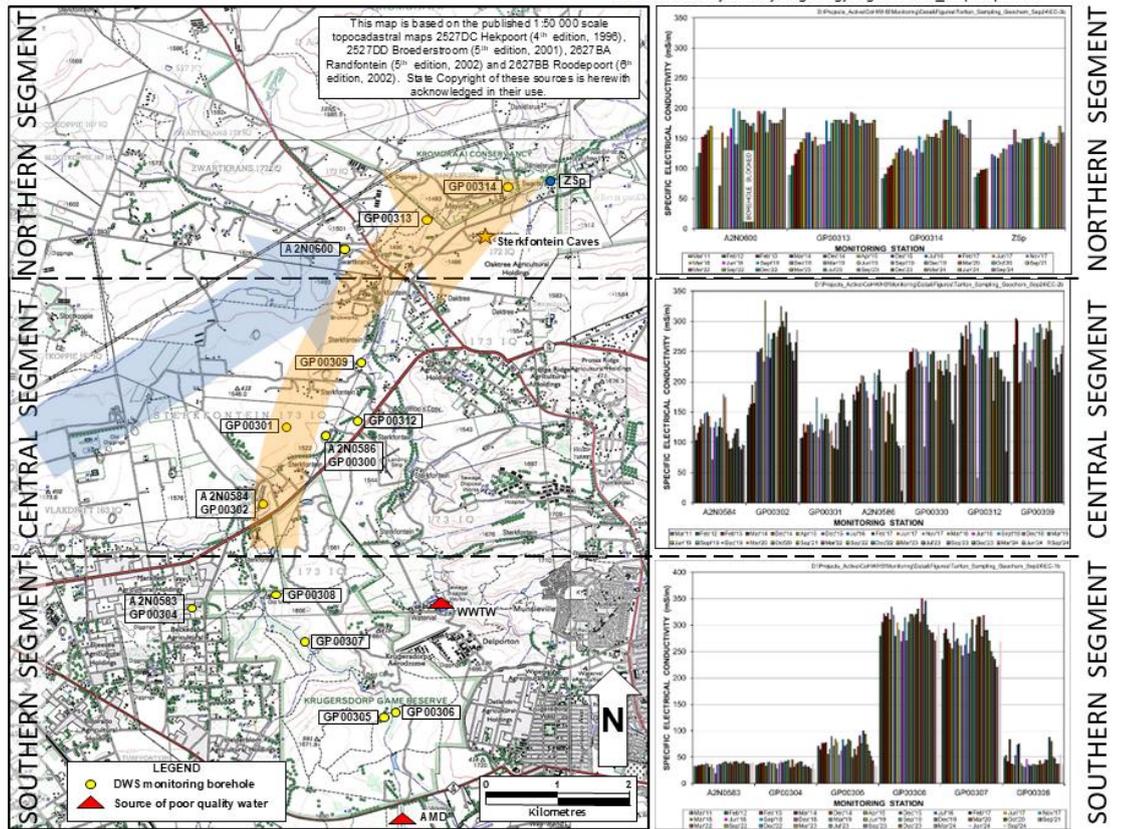
Figure 26 Distribution of DWS monitoring boreholes with SEC pattern and trend as bar graphs; brown arrow denotes principal direction of impacted groundwater flow, and blue arrow direction of natural karst groundwater flow.
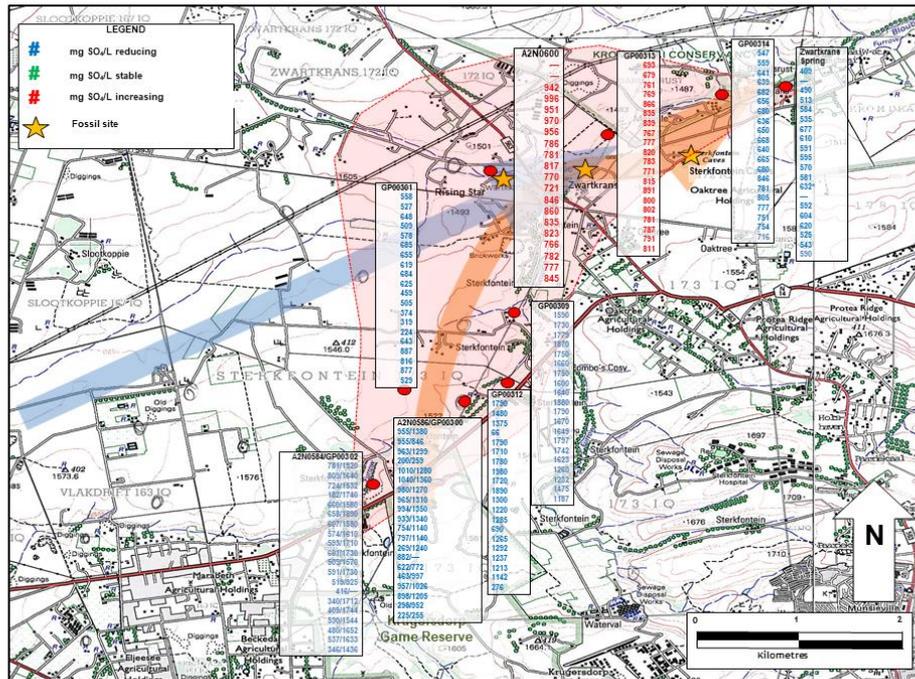
Figure 27   Sulphate level distribution in groundwater within the Zwartkrans Basin across 21 sampling periods from July 2016 to September 2024, also showing the principal vectors of allogenic recharge (brown arrow), autogenic recharge (blue arrow), the postulated footprint (shaded area) of a mine water impact in the karst aquifer, and SEC trend as INCREASING (red text), STABLE (green text) or REDUCING (blue text).

5.2.3   Sterkfontein Cave

Table 7 presents the water chemistry results of groundwater samples collected at Sterkfontein Cave between March 2019 and September 2024. The recent results from September 2024 align with historical values reported for the site. None of the reported chemistry variables exceed the respective SANS (2015a) health-related limits for potable water. However, the microbiological quality is compromised, as total coliform bacteria consistently exceed the health-related limits, indicating the influence of poorer quality surface water on the karst groundwater. Notably, the E. coli concentration in September 2024 was lower than that recorded in March 2024. The moderately alkaline pH reflects the ongoing neutralizing effect of the carbonate strata. Additionally, due to the Sterkfontein Cave's location away from the main groundwater flow towards Zwartkrans Spring, the lake's water chemistry appears less affected by mine water influences

Table 7 Water chemistry results of samples collected at Sterkfontein Cave between March 2019 and September 2024.

Variable	Mar 19	Jun 19	Sep 19	Dec 19	Mar 20	Jul 20	Sep 20	Sep 22	Dec 22	Mar 24	Sep 24	SANS (2015a)[1]
pH (–log10αH+)	8.0	8.1	8.1	8.2	7.9	4.7	7.9	8.0	8.2	7.8	7.9	5.0–9.7
SEC (mS/m)	92	92	95	94	100	90	100	96	94	88	92	<170
Ca (mg/L)	90	89	88	89	91	95	88	88	70	86	87	n.s.
Mg (mg/L)	53	54	54	53	50	58	51	51	51	50	51	n.s.
Na (mg/L)	35	37	33	34	35	38	33	35	35	33	33	<200
K (mg/L)	1.5	1.6	1.5	1.5	2	1.5	1.3	1.5	1.5	1.5	1.6	n.s.
Cl (mg/L)	37	37	36	37	38	37	37	36	36	35	36	<300
SO4 (mg/L)	273	271	259	262	298	286	267	262	270	246	245	<500
HCO3 (mg/L)	148	146	148	142	146	160	145	147	147	153	153	n.s.
NO3+NO2 (mg N/L)	7.1	7.0	6.6	7.0	7.4	7.6	7.0	7.1	7.6	7.2	7.6	<11
Si (mg/L)	5.9	7.0	5.8	6.0	5.8	5.6	6.0	6.3	5.9	6.5	6.0	n.s.
Fe (mg/L)	0.02	0.31	0.02	0.17	0.04	<0.01	0.03	0.03	<0.02	0.39	0.88	<2
Mn (mg/L)	<0.01	0.32	<0.01	0.03	0.02	0.02	0.01	<0.01	<0.03	<0.03	0.11	<0.5
Al (mg/L)	0.03	0.14	0.02	0.05	0.03	0.02	0.02	<0.01	<0.02	0.18	0.15	<0.3
Total coliform bacteria (MPN/100 mL)	1046.2	125.9	35.5	248.1	547.5	78	32.3	78.9	1299.7	579.4	488.4	<10
E. coli (MPN/100 mL)	<9.8	4.1	<1.0	3.1	3.1	<1.0	<1.0	14.4	12.2	5.2	<1.0	n.d.

[1]   Standard health-related limit for consumption of 2 L/d over 70 years by a 60 kg person

n.s   no standard

n.d   not detected

5.2.4 Dolomitic Springs

As part of Project GT/WHS/021/2022 the CSIR is responsible for the bi-annual water quality monitoring of the dolomitic springs in the study area (**Figure 28**). Sampling occurred in March 2024 and September 2024, with the corresponding results outlined in **Table 8.** Additionally, **Section 5.2**. provides a comparison between historical and recent water quality data concerning the Zwartkrans Spring.

Barring the Zwartkrans and Aquamine springs, the groundwater quality from the main dolomitic springs is of good quality as indicated by the chemical parameters included in the sample data between March 2024 and September 2024. Consistent with previous results from September 2023 and March 2024 (Mvandaba and Moloi, 2024), the chemical analysis of water from the Zwartkrans Spring indicates a probable impact from mine water, as elevated sulphate levels surpass established health-related limits (SANS 241:1, 2015a). Similarly, the groundwater from the Aquamine Spring continues to exhibit relatively higher concentrations of manganese, iron, and aluminium that exceed the standard health-related limits as noted in previous reports (Mvandaba and Shadung, 2023; Mvandaba and Moloi, 2024).

These minerals occur naturally in karst sediments, and their fluctuation may be linked to the resuspension of minerals due to sediment movement during periods of heavy rainfall (Diković and Koželj, 2015) and runoff.

With the exception of the Zwartkrans, Plover's Lake and Nouklip springs, the microbiological quality of the water is compromised by total coliform bacteria, which far exceed standard health-related limits. In water resource management, the counts of total coliform bacteria and *E. coli* are indicators of the sanitary quality of water and the degree of pollution. Total coliform bacteria are common in natural environments, such as soil, vegetation, and aquatic ecosystems, and may not necessarily be harmful. However, elevated counts indicate vulnerability to contamination by more harmful microorganisms. *E. coli*, a strain of coliform bacteria found only in the intestines of mammals, including humans, can enter natural environments via poorly treated municipal effluent, stormwater runoff, manure used in agricultural practices, and droppings from domestic animals and wildlife. The South African Water Quality Guidelines (DWAF, 1996) do not specify a target range for coliform in aquatic ecosystems, but the drinking water guidelines (SANS 241:1, 2015) stipulate less than 10 MPN/100 mL for total coliforms and zero detection for *E.coli*. According to the World Health Organization (2011), a count of 1–10 MPN/100 mL is regarded as low risk, 11–100 MPN/100 mL as moderate risk, and greater than 100 MPN/100 mL as high risk. E. coli counts greater than 1,000 MPN/100 mL are considered extreme high risk. *E.coli* concentrations measure at <1.0 MPN/100 ml for most of the springs indicating low risk, however the elevated E.coli counts measured in September 2024 at the Kromdraai, Tweefontein and Nash Spring categorised the springs as moderate to high risk, respectively. Due to its location within the Bloubankspruit channel, groundwater from the Kromdraai spring may intermingle with surface water, potentially affecting the results observed. Additionally, the Tweefontein spring sampling site is exposed to surface runoff and animal activity, which could influence water quality. However, the elevated *E. coli* levels detected at Nash Spring are unusual, warranting further sampling to investigate the cause of this anomaly.
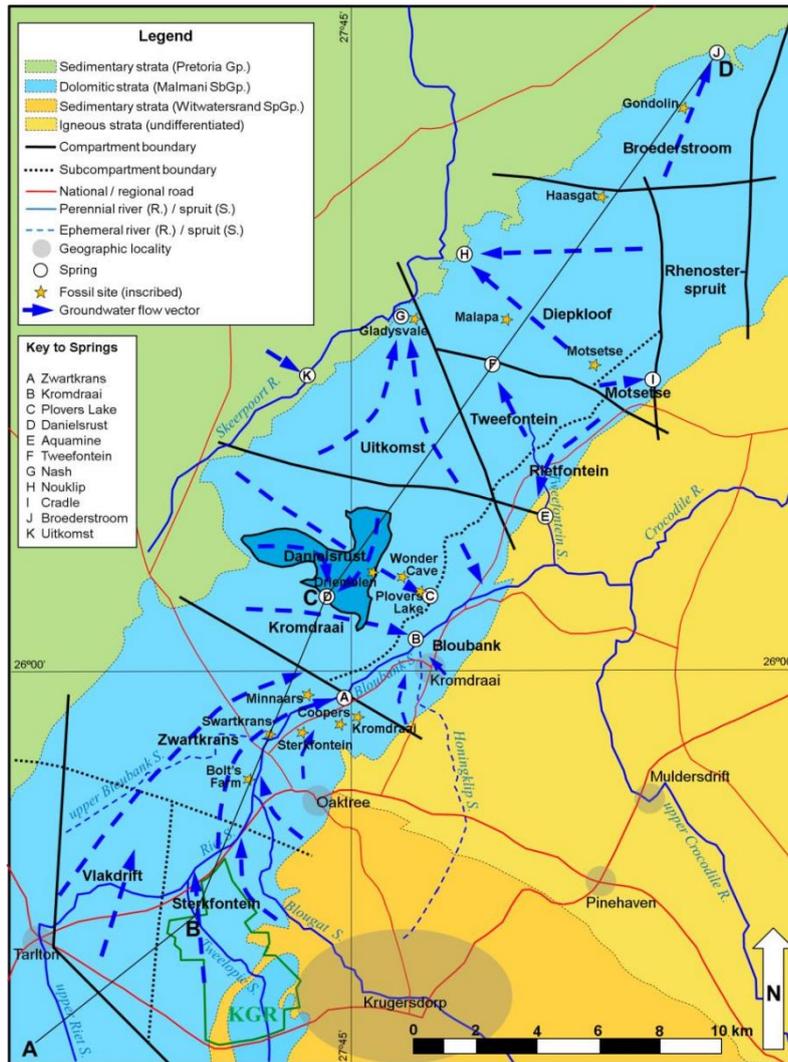
Figure 28   Map showing the regional geology of the study area, dolomitic compartment boundaries, groundwater flow vectors and the major dolomitic springs.

Table 8   Water chemistry and microbiological results of samples collected at the major dolomitic springs during March 2024 and September 2024.

Variable	Zwartkrans Spring Mar 24	Zwartkrans Spring Sep 24	Kromdraai Spring Mar 24	Kromdraai Spring Sep 24	Plovers Lake Spring Mar 24	Plovers Lake Spring Sep 24	Danielsrust Spring Mar 24	Danielsrust Spring Sep 24	Aquamine Spring Mar 24	Aquamine Spring Sep 24	Tweefontein Spring Mar 24	Tweefontein Spring Sep 24	Nouklip Spring Mar 24	Nouklip Spring Sep 24	Nash Spring Mar 24	Nash Spring Sep 24	Cradle Sp Mar 24	Cradle Sp Sep 24	Broederstroom Spring Mar 24	Broederstroom Spring Sep 24	SANS (2015a)(1)
pH (–log10αH+)	7.8	7.7	8.0	8.1	8.2	8.0	8.0	8.0	7.9	7.7	8.0	7.9	8.1	8.0	8.1	7.9	8	7.8	7.9	7.8	5.0–9.7
SEC (mS/m)	142	146	70	72	37	36	62	29	56	58	37	39	26	39	37	25	28	64	52	54	<170
Ca (mg/L)	168	170	70	69	47	40	32	30	61	61	43	42	28	43	43	27	73	69	59	57	n.s.
Mg (mg/L)	82	82	41	41	27	25	19	18	35	35	26	25	17	25	26	16	45	42	37	35	n.s.
Na (mg/L)	60	61	1.3	20	3.0	1.8	20	1.2	3.8	3.5	1.2	1.3	1.4	1.2	1.2	1.3	3.6	3.3	1.6	1.3	<200
K (mg/L)	<3	2.8	0.8	0.9	<0.6	<0.6	<0.6	<0.6	0.9	0.9	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	n.s.
Cl (mg/L)	42	45	22	25	2.5	<2.0	3.2	2.3	5.9	30	3.5	3	<2.0	<2.0	4.0	<2.0	4.3	7.3	3.3	2.2	<300
SO4 (mg/L)	590	602	160	158	22	5.5	5.2	4.7	12	11	6.9	7.1	1.9	5.8	5.6	1.9	21	17	22	18	<500
Alkalinity as CaCO3 (mg/L)	149	149	167	136	198	191	141	138	284	280	198	196	135	202	201	137	335	338	273	272	n.s.
NO3+NO2 (mg N/L)	8.4	8.8	3.5	4.0	0.73	0.77	0.78	1.4	0.34	0.21	0.73	0.82	0.21	0.37	0.33	0.22	0.11	0.11	0.58	0.56	<11
Si (mg/L)	6.4	6.4	5.6	5.6	6	5.6	5.4	5.1	12	8.8	4.9	4.7	5	4.9	5	5	7.7	7.4	4.8	4.7	n.s.
Fe (mg/L)	0.04	0.06	0.09	0.1	0.03	<0.01	0.02	<0.01	7.4	5.0	0.04	0.07	0.05	<0.01	0.2	0.01	0.32	0.05	0.09	0.02	<2
Mn (mg/L)	<0.01	<0.01	0.01	0.01	0.02	<0.01	<0.01	<0.01	0.68	0.92	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	0.08	<0.01	<0.01	0.01	<0.5
Al (mg/L)	<0.01	0.05	0.03	0.03	<0.02	<0.02	<0.02	<0.02	3.3	1.5	<0.02	0.02	<0.02	<0.02	<0.02	<0.02	0.17	0.03	<0.2	<0.02	<0.3
Total coliform bacteria (MPN/100 mL)	>2419.6	8.6	>2419.6	1119.9	187.2	4.1	45.7	64.5	>2419.6	>2419.6	387.3	2419.6	50.4	1.0	32.7	145.5	435.2	74.9	14.6	22.6	<10
E.coli (MPN/100 mL)	24.1	<1.0	260.3	6.3	<1.0	<1.0	<1.0	2.0	2.0	3.1	8.6	6.2	1.0	<1.0	4.1	101.4	<1.0	<1.0	<1.0	<1.0	n.d.

(1)- Standard health-related limit for consumption of 2 L/d over 70 years by a 60 kg person; n.s. – no standard; n.d. – not detected

6   RIVER HEALTH ASSESSMENT

In accordance with the SLA governing project GT/WHS/021/2022, the water resources monitoring program includes an assessment of river health on the COHWHS property based on macroinvertebrate biomonitoring and toxicity screening assays. This assessment is typically conducted biannually at the end of the dry and wet seasons, i.e., in September and March. However, the river health assessments scheduled for September 2024 could not be performed due to the unavailability of an accredited SASS5 practitioner. CSIR is in the process of recruiting an accredited practitioner and the assessment will be conducted in the next planned biannual assessment event. Therefore, the analysis included in this section is as presented for the April 2023 to September 2023 reporting (Mvandaba *et al.*, 2023).

Macroinvertebrate assessment is widely recognized as an effective means of determining river health. Benthic macroinvertebrates are valuable for bioassessments due to their visibility, ease of identification, rapid life cycles, and largely sedentary habits (Dickens and Graham, 2002). Bioassessment techniques have been developed over the past three decades with varying complexity. The South African Scoring System 5 (SASS5), developed by Chutter (1994), has undergone refinement and now forms the backbone of the National River Health Programme. Key changes include tighter definitions of techniques, sampling and analytical methods, and the introduction of quality control procedures.

SASS5 is suitable for assessing river water quality and health and can be used to:
- Assess the ecological state of aquatic ecosystems.
- Assess spatial and temporal trends in ecological state.
- Identify emerging problems.
- Set objectives for rivers.
- Assess the impact of developments.
- Predict changes in ecosystems due to developments.
- Contribute to the determination of the Ecological Reserve (National Water Act, 1998).

The river health assessment targets two sites on the largely natural Skeerpoort River and two sites on the impacted Bloubankspruit. The sites on the Skeerpoort River are labelled S@NSp and S@HTL, while the sites on the Bloubankspruit are respectively labelled BB@M and BB@NOE (**Figure *29*)**.

In the case of the springwater-driven Skeerpoort River, the 'upper' site is located on a small (short) perennial tributary at a distance of ~125 m downstream from a major karst spring, and the 'lower' site at a position

~4000 m further downstream where the river has left the dolomitic substrate and traverses sedimentary strata (mainly shale). In the case of the Bloubankspruit, both the 'upstream' and 'downstream' sites experience the combined impact of mine water and municipal wastewater discharges. The difference is that the upper site is located before the first substantial springwater (Zwartkrans Spring) input, and the lower site after the last substantial springwater (Kromdraai Spring) input.

The sites on the Bloubankspruit replicate two of those surveyed earlier as part of a CSIR Strategic Research Project (SRP) assessment of the biotic response in streams of the Western Basin that receive neutralised acid mine drainage. The outcome of this project is reported in Hill *et al.* (2014).

The Skeerpoort River sites ostensibly represent largely undisturbed, natural conditions for reference purposes, although the lower site is located ~120 m downstream of a weir and adjacent to a trout farm that discharges into the river. The lower site has been surveyed on numerous occasions in the past (Fourie *et al.*, 2014 and references therein). No published material is available for the aquatic ecosystem status of the upper site, and it is not known whether this drainage was surveyed prior the establishment of the COHWHS water resources monitoring programme. In any event, this site represents as natural a condition of a spring water-driven headwater stream in a karst landscape as can be found in the COHWHS.
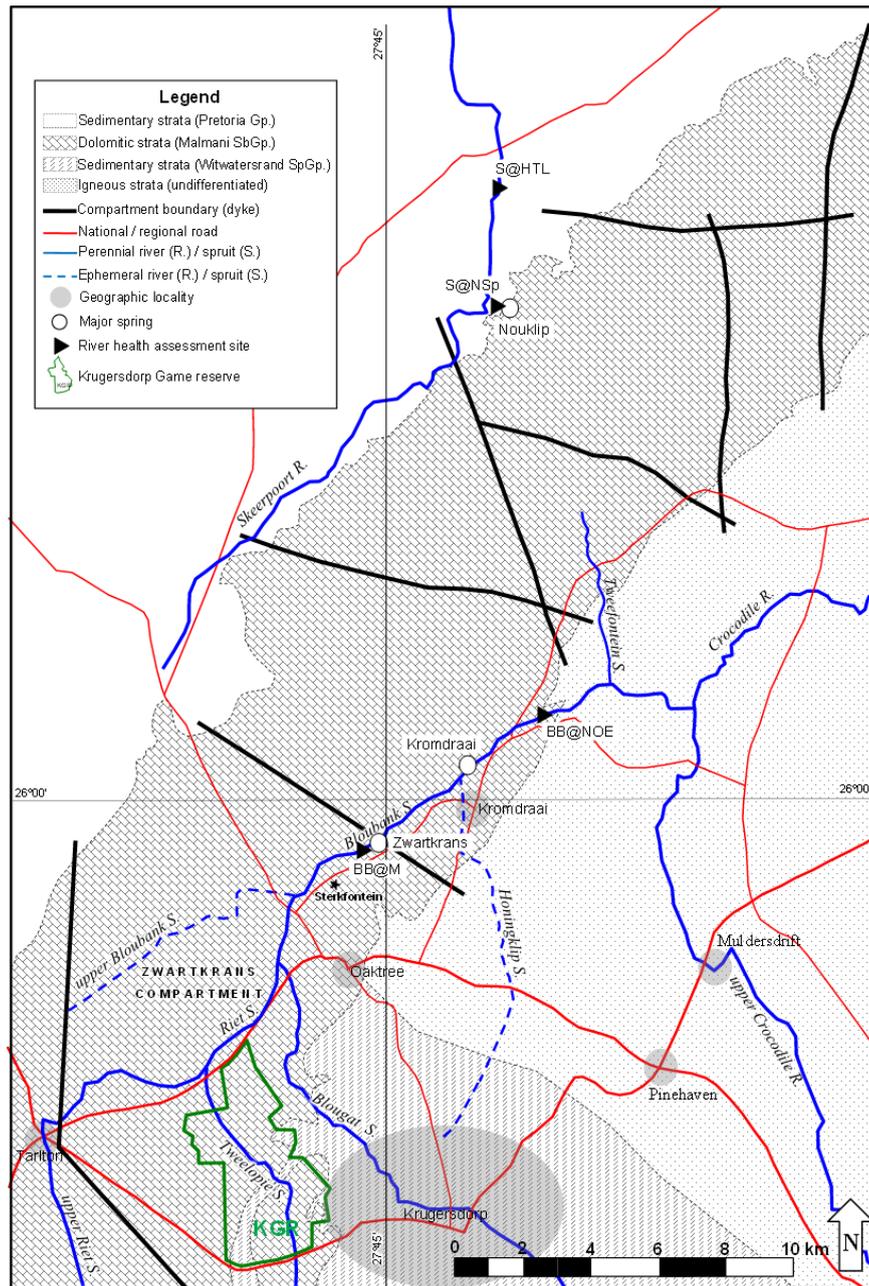
Figure 29   Map showing sites of relevance to the river health assessment.

6.1   Assessment & Data Analysis

The assessment entailed the application of the integrated habitat assessment system IHAS (McMillan, 1998) and SASS5 (Dickens and Graham, 2002) procedures to evaluate respectively the instream habitat quality and associated benthic macroinvertebrate integrity at each site. Together, the procedures have proven in countless studies nationally their efficacy in assessing aquatic macroinvertebrate diversity as a function of instream habitat and water quality. Impairment of either habitat or water quality reduces biodiversity and, therefore, results in a 'poorer' river condition (generically referred to as river health) when compared to the natural (or reference) condition. River health is classified according to the criteria set out in **Table 9** below. A description of the survey sites is given in **Annexure A**.

Table 9 River Health Classification (Dallas, 2007).

Biological Band / Ecological Category	SASS5 Score	ASPT Score	Band / Category Name	Description
A	>104-180	>5.8-8	Natural	Unmodified natural
B	>71-104	>4.8-5.8	Good	Largely natural with few modifications
C	>53-71	>4.2-4.5	Fair	Moderately modified
D	>42-53	0-4.2	Poor	Largely modified
E/F	0-42		Seriously modified	Seriously modified

6.2 Macroinvertebrate Biomonitoring Results

6.2.1 Current Assessment Outcome

A synthesis of the current results is presented as a synoptic assessment in **Table 10**, and the results discussed in **Section 6.2.2.** The current macroinvertebrate biomonitoring results have indicated an improvement in the general river health and ecological category at both sites on the Skeerpoort River, i.e. S@NSp and S@HTL, despite the noticeable disturbance at the S@HTL site due to cutting away of the natural vegetation and disturbance of the instream habitat as evidenced by the presence of stones, gravel and as a result of fast-flowing water due to flooding. Upstream on the Bloubankspruit, while there was a clear decline in the quality of water and instream habitat at the BB@M site, the ecological category remained the same. As a result of the recent flood events in the study area, the streamflow at the BB@NOE site was found to be too turbid and deep to allow safe assessment of the river health. However, water samples for the assessment of the toxicity, chemistry and microbiological quality were collected.

Table 10 Synoptic river health assessment outcome for September 2023.

SITE	Date	Ecological category	Condition	Description
S@NSp	14/09/2023	A	Natural	Unmodified natural
S@HTL	14/09/2023	A	Natural	Unmodified natural
BB@M	16/03/2023	E/F	Seriously modified	Seriously modified
BB@NOE	14/03/2023	Macroinvertebrate biomonitoring could not be conducted		

6.2.2 Comparison with Historical Results and General Observations

6.2.2.1 Skeerpoort River

S@NSP

In **Table 11**, seasonal sampling (spring and summer) is compared for site S@NSp.

The inclusion of this site in the river health assessment aims to analyse the suitability of site S@HTL as a reference site for the COHWHS property even though it is located downstream of the karst area.

The surrounding area is largely undisturbed, natural vegetation. A few hundred metres upstream there was evidence of heavy erosion from flooding and cutting of the natural vegetation which could easily affect the invertebrate sampling scores. In the current monitoring period (March 2023), the number of taxa was the least in all sampling period due to lack of good habitat for macroinvertebrates sampling.

The River Health Category rating for this site in March 2023 was B (good) with an ASPT score of 5.8 – 5.9. It is expected that this particular site will continue to oscillate between a Category B and C.

S@NSp is a headwater stream, and macroinvertebrate diversity in headwaters do tend to differ, but are generally lower than in the middle reaches of a river network (widely reported in numerous sources, and reviewed in Clarke *et al.*, 2008). This would also account for higher scores in the downstream Skeerpoort River site (even though it is downstream of a trout farm).

Table 11 Comparison of present biomonitoring results for site S@NSp with previous results.

Site: S@NSp		River: Grootspruit (tributary of the Skeerpoort River)							
		SASS associated scores						Dominance *	
Date	Ecological category	SASS 5	Taxa	ASPT	IHAS (%)	Highest Sensitivity	Total Invertebrates	Dominant Feeding Group	Dominant Taxa
27/02/2018	C	105	18	5.8	71	12	130	Predators	*Baetidae*
26/09/2018	B	95	15	6.3	73	10	238	Predators	*Corixidae*
26/03/2019	C	99	17	5.8	75	12	160	Predators	*Gomphidae*
16/09/2019	C	70	12	5.8	70	12	169	Predator	*Pleidae*
02/03/2020	B	138	21	6.6	66	14	338	Predator	*Palaemonidae*
14/09/2020	C	53	14	4.5	59	12	229	Predator	*Simuliidae*
19/09/2022	*Sampling could not be conducted*								
14/03/2023	B	31	6	5.17	40	8	NA	Predator	*Baetidae*
14/09/2023	A	102	15	6.8	40	8	N/A	Predator	*Batidae*

S@HTL

In **Table 12** seasonal sampling for site S@HTL is compared. The River Health Category generally borders between A (Natural), and B (Good) while it was categorized as D only in one occasion (September, 2020).

The sampling area has a pool of slow-moving/still water, leading to a narrower region of faster-flowing riffles. Most habitats were well represented. The Skeerpoort River at this site is more in the middle reaches of the river system, and as such is expected to have a larger diversity of macroinvertebrates. The current ASPT score was the highest of all sampling runs.

Table 12 Comparison of present biomonitoring results for site S@HTL with those of the Fourie *et al.* (2014) "site B" results.

Site: S@HTL		River: Skeerpoort River						Dominance *	
		SASS associated scores							
Date	Ecological category	SASS5	Taxa	ASPT	IHAS	Highest Sensitivity	Total Invertebrates	Dominant Feeding Group	Dominant Taxa
##/01/2014[1]	A	~200[2]	~34[2]	~6.0[2]	-	-	-	-	-
13/02/2018	A	185	27	6.9	72%	13	653	Collector-Gatherers	*Tricorythidae*
17/10/2018	B	170	29	5.9	73%	12	524	Collector-Gatherers	*Baetidae*
25/03/2019	B	170	28	6.1	76%	13	437	Predators	*Baetidae*
17/09/2019	B	99	16	6.2	70	12	354	Predators	*Baetidae and Pleidae*
02/03/2020	A	90	13	6.9	77%	15	399	Predators	*Pleidae*
15/09/2020	D	70	16	4.3	69%	12	328	Predators	*Baetidae*
19/09/2022	Sampling could not be conducted								
14/03/2023	A	103	14	7.36	82%	12	NA	NA	*Caenidae*
14/09/2023	A	99	14	7.07	82%	12	NA	NA	*Caenidae*

1 From Fourie *et al.* (2014), 2 Approximate value interpolated from bar graph in Fourie *et al.* (2014)

6.2.2.2 Bloubankspruit

BB@M

The study by Hill *et al.* (2014) provides a similarly quite recent assessment against which to gauge the present river condition. This is provided in **Table 13** (site BB@M) and **Table 14** (site BB@NOE).

Site BB@M typically has in the past showed a variety of good habitat with large areas of sand and stones in the river channel and leafy vegetation. However, as shown in the **Table 12,** there is a clear trend in the deterioration of aquatic habitats (biotopes).

The River Health Category remains similar to the previous sampling campaign as it scored E/F. Furthermore, it was noticeable that the ASTP score was the worst compared to the previous sampling campaigns while the habitat quality was very poor of all the sampling trips due to site destruction owing to recent flooding.

Table 13 Comparison of present biomonitoring results for site BB@M with those of the Hill *et al.* (2014) study.

Date	Ecological category	SASS associated scores						Dominance	
		SASS5	Taxa	ASPT	IHAS (%)	Highest Sensitivity	Total Invertebrates	Dominant feeding group	Dominant Taxa
23/02/12	E/F	32	9	3.6	57				
16/05/12	E/F	53	14	3.8	81	13	653	Collector-Gathers	*Tricorythidae*
24/10/12	E/F	35	10	3.5	72	12	524	Collector-Gathers	*Baetidae*
06/03/13	E/F	52	13	4	74	13	437	Predator	*Baetidae*
15/08/13	E/F	34	9	3.8	65	12	277	Predators	*Baetidae* and *Pleidae*
12/12/13	E/F	38	10	3.8	61				
13/02/18	E/F	27	8	3.4	67	13	653	Collector-Gathers	*Tricorythidae*
25/09/18	E/F	48	11	4.4	71	12	524	Collector-Gathers	*Baetidae*
28/03/19	E/F	46	12	3.8	66	13	437	Predator	*Baetidae*
16/09/19	E/F	36	10	3.6	65	12	277	Predators	*Baetidae* and *Pleidae*
04/03/20	E/F	27	8	3.9	56%	6	735	Predators	*Chironomidae, Ceratopogenidae and Culicidae*
16/09/20	E/F	13	4	3.2	75	5	382	Predators	*Chironomidae*
19/09/22		Sampling could not be conducted							
06/12/22	E/F	35	12	2.9	49	6	861	Predators	*Chironomidae*
16/03/23	E/F	15	6	2.5	55%	5	861	Predators	*Chironomidae*
13/09/2023	E/F	16	6	2.6	35%	5	861	Predators	*Chironomidae*

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BB@NOE

As illustrated in Table 14, the ecological state of the Bloubankspruit at the Nedbank Olwazini has been observed to be variable over the various monitoring periods. Less diversified than the upstream site, the instream habitat at this location is largely made up of heavy stones and rocks that pose a safety threat to the river health assessor. There is little sand, and the overhanging vegetation is often limited. The SASS5 and ASPT scores continue to be low, as seen in Table 14 below.

Table 14   Comparison of present biomonitoring results for site BB@NOE with those of the Hill *et al.*

Site: BB@NOE		River: Bloubankspruit							
		SASS associated scores						**Dominance ***	
Date	Ecological category	SASS5	Taxa	ASPT	IHAS (%)	Highest Sensitivity	Total Invertebrates	Dominant Feeding Group	Dominant Taxa
23/02/12	E/F	52	12	4.3	52	6	206	Collector-Filterers	*Hydropsychidae*
16/05/12	E/F	41	10	4.1	59	6	269	Collector-Gatherers	*Baetidae*
24/10/12	C	59	11	5.4	61	12	230	Collector-Gatherers	*Baetidae*
06/03/13	B	60	10	6.0	55	12	225	Collector-Gatherers	*Baetidae*
12/12/13	D	32	6	5.3	53	12	329	Collector-Gatherers	*Baetidae*
13/02/18	D	57	12	4.8	58	12	234	Collector-Gatherers	*Baetidae*
25/09/18	E/F	30	8	3.8	55	6	275	Predators	*Corixidae*
25/03/19	E/F	33	8	4.1	54	6	178	Predators	*Simuliidae*
17/09/19	E/F	64	14	4.6	58	8	781	Predators	*Ceratopogenidae and Chironomidae*
04/03/20		Sampling could not be conducted							
16/09/20	E/F	38	11	3.4	50	6	320	Predators	*Chironomidae*
19/09/22		Sampling could not be conducted							
06/12/22		Sampling could not be conducted							
04/03/23		Sampling could not be conducted							
13/09/2023		Sampling could not be conducted							

Previous results indicate a deterioration in the system as the ecological category is consistently in the E/F category. During the last three monitoring events of 2022/23, the river health assessment at this site could not be conducted due to highly turbulent and unsafe flow that posed a danger to the assessor.

According to (Dickens and Grahams, 2002), it is the prerogative of the assessor to desist from sample collection if she/he considers the conditions in the river or the surroundings to be unsafe.

6.3   Toxicity Testing

Laboratory toxicity tests are used worldwide to manage environmental resources such as water quality and are considered to be the first step in a tiered approach in establishing guidelines for setting up maximum acceptable concentrations of specific pollutants (Muller and Palmer, 2004). The use of bioassays incorporating complex mixtures has proven to be a relevant and complementary tool in evaluating the adverse toxic effects of effluents and receiving waters (Rand *et al.*, 1995; Grothe *et al.*, 1996). The techniques are site specific, and account for both point and non-point sources of aquatic contamination and uncharacteristic sources of toxicity and can detect their potentially unknown interactions (Smolders *et al.*, 2003; Martins *et al.*, 2007). However, no single toxicity test has proven to be suitable to assess all adverse ecological effects because individual organisms differ in susceptibility and sensitivity to different chemicals (Rand *et al.*, 1995; DWAF, 2003). Therefore, several different bioassays at different levels of biological complexity and trophic levels need to be used simultaneously to adequately assess if a potential hazard posed (Jergentz *et al.*, 2004).

The approaches used internationally in water quality monitoring programmes include the Whole Effluent Toxicity (WET), used in the USA, the Direct Toxicity Assessment (DTA), used in the UK and the 'Totale Effluent Milieu' hygiene (TEM) or 'whole effluent environmental risk' approach, used in the Netherlands (DWAF 2003). These approaches are based on similar fundamental concepts by using an array of acute or chronic toxicity test endpoints and in certain instances such as TEM, and other indirect hazard parameters such as oxygen depletion potential, bioaccumulation, and mutagenicity to ascertain ecological effects of pollutants.

In South Africa, the Department of Water Affairs and Forestry (DWAF) presently known as the Department of Water and Sanitation (DWS) has adopted a multifaceted approach referred to as the 'direct estimation of ecological effect potential' (DEEEP) which includes these international approaches (using TEM as a foundation) and has become an integral first-tier tool used in the ecological hazard assessment of complex waste discharges (DWAF, 2003). The DEEEP approach uses representative organisms from different trophic levels of the food chain (fish, invertebrates, microalgae, and bacteria) and endpoints (both lethal and sublethal) to reflect the overall impact of toxicants in the water samples, with provision to define acceptable ecological hazards to protect aquatic ecosystems (Jooste and Herbst 2004). The same suite of hazard assessment methods was selected for inclusion in the National Toxicity Monitoring Programme (NTMO) for surface water (DWAF, 2005). The main objectives of the NTMO are to monitor South African water resources in terms of (a) the toxic effects on selected organisms and (b) selected potentially toxic substances.

The two rapid and relatively inexpensive internationally standardized toxicity bioassays that form part of the DEEEP and NTMP were adapted and incorporated into the present study. These were (1) the water flea (Daphnia magna) mortality test, and (2) the microalgal (*Raphidocelis subcapitata* (previously: *Selenastrum capricornutum*)) growth inhibition test.

Differential responses of organisms such as these represent diverse physiological capabilities and reach in aquatic systems that can help focus field studies where non-target effects due to off-site movement, for example acid mine drainage and wastewater effluents, are suspected. Water fleas (Daphnia spp.) are routinely employed to detect chemical pollution in river waters based on their toxicity (Rand *et al.*, 1995). Daphnia sp. has been used for many years as 'standard aquatic test species'. Unicellular microalgae form the basis of the energy flow in the aquatic trophic chain and show great advantage for use in estimating the toxicity of effluents and receiving waters (Sbrilli *et al.*, 2005). They are relatively sensitive to a variety of pollutants and are easy to handle and have a short life cycle (Rioboo *et al.* 2001).

Toxicity Testing Results

The results are reported per bioassay. Freshwater toxicity screening tests with bacteria Vibrio fischeri, crustacean Daphnia magna and microalgae Selenastrum capricornutum were performed on surface water samples collected at the Skeerpoort River sites (S@NSP and S@HTL) and the two sites (BB@M and BB@NOE) on the Bloubank Spruit. The additional site for this test includes BG@N14, upstream of BB@M. For this study, 15-minute vibrio fischeri, acute 48-hour D. magna tests and 72-hour S. capricornutum were conducted under static conditions to assess the short-term toxicity potential of water samples from the selected sites using organisms of three different trophic levels. The test conditions and test acceptability criteria are summarised in **Tables B.1, B.2** and **B.3** in the methods and materials section (**ANEXURE B**).

At the beginning of the experiments, physicochemical parameters were measured with a hand-held Hach HQ 40D multi-parameter (temperature, pH, electrical conductivity and dissolved oxygen) meter. The results of the three toxicity tests are summarised below.

15-Minutes *Vibrio fischeri*

The *V. fischeri* luminescence can be inhibited (-) or stimulated (+) where the inhibition above 20% indicates toxicity and the stimulation greater than 20% indicates potential eutrophication. Stimulation beyond the limited threshold is also not good because it indicates pollution from substances that are high in nutrients leading to excess bacterial, algal, and plant growth. The potential sources can be domestic, landfills, and other industrial wastes.

June 2024 Results

15-minutes analysis of the *V. fischeri* luminescence inhibition (-) / stimulation (+) test was performed and the results after a 15-minutes exposure period were as follows: -12.21, -7.30, and -2.76% for sample BG@N14, BB@M, and BB@NOE respectively (***Table 15***). The samples from all the river systems showed a luminescence inhibition of *V. fischeri*. BG@N14 had the highest inhibition (12.21%), and BB@NOE with least inhibition (-2.76%), however, there were no toxicity effects reported because all the samples were within the acceptable limits (-20 – 20%).

Table 15 Effect percentage inhibition/stimulation of *V. fischeri* on samples after 15-minute luminescence. test.

Sample	Initial mean intensity	Final mean intensity	Inhibition/stim ulation (%)
BG@N14	-220.50	-353.36	-12.21
BB@M	-387.71	-592.57	-7.30
BB@NOE	-437.93	-642.64	-2.76

September 2024 Results

The *V. fischeri* September results were recorded at 52.98, 28.59, 24.87,26.71, and 25.43% for site BB@M, BG@N14, BB@NOE, S@NSP, and S@HTL respectively (**Table *16***). All the samples from different sites showed the *V. fischeri* growth stimulation that was beyond the allowed limits (> 20%). Site BB@M had the highest stimulation rate of 52.98% showing a greater accumulation of nutrients which resulted in intensified eutrophication. The other 4 sites were just 5 to 8% above the threshold. Overall, all the river systems are filled with nutrients which is a sign of pollution either from landfills or other potential domestic and industrial waste.

Table 16 Effect percentage inhibition/stimulation of *V. fischeri* on samples after 15-minute luminescence test.

Sample	Initial mean intensity	Final mean intensity	Inhibition/stimulation (%)
BB@M	143.21	89.71	52.98
BG@N14	-289.07	-283.57	28.59
BB@NOE	-373.64	-374	24.87
S@NSP	-412.07	-402.36	26.71
S@HTL	-415.07	-412.36	25.43

48-Hour *Daphnia Magna* Test

June 2024 Results

Table *17* summarises the results of D. magna exposed to the undiluted test samples BB@NOE, BB@M and BG@N14. The tests were accepted as no mortality (≤ 10%) was observed in the Control. At the end of the exposure period (48 hours), the highest mortality of 85% was evident in sample BG@N14, followed by a 35% mortality from BB@M sample. The mortality percentage remained low in Skeerpoort Spruit samples. The increased mortality in sample BG@N14 indicates that the water from this site is very toxic and a similar trend was observed for V. fischeri growth inhibition test where the inhibition rate was also high in this site even though it was within the limits, however higher than the other study sites.

Table 17   Results of the *D. Magna* screening assays expressed as percentage mortality after 24 and 48 hours.

Sample	Time (Hrs)	Mortality (No. of organisms)	Mortality (%)
Control	24	1	5
	48	2	10
BB@NOE	24	2	10
	48	2	10
BB@M	24	3	15
	48	5	35
BG@N14	24	16	80
	48	17	85

September 2024 Results

Table *18* summarises the results of D. magna exposed to the undiluted test samples S@NSP, S@HTL, BB@NOE, BB@M and BG@N14. The tests were accepted as no mortality (≤ 10%) was observed in the Control. At the end of the exposure period (48 hours), the highest mortality was obtained in samples BG@N14 and BB@M with a mortality rate of 100% and 80% respectively. The mortality percentage of Skeerpoort Spruit samples (i.e. S@HTL and S@NSP) was also higher. The high mortality rate as shown in the results can be an indication of worsened conditions in these areas. These results align with those obtained for September V. fischeri and algal tests. The bacterial and algal growth was stimulated above the acceptable threshold indicating high pollution. Daphnids are very sensitive to any type of pollution because they also compete for oxygen and prefer certain conditions (pH, DO, temperature and conductivity) while pollutants can alter such conditions making it difficult for them to survive. Hence, the samples that promoted excess growth for microalgae and V. fischeri resulted in high mortality for the daphnids indicating high toxicity.

Table 18 Results of the *D. Magna* screening assays expressed as percentage mortality after 24 and 48 hours.

Sample	Time (Hrs)	Mortality (No. of organisms)	Mortality (%)
Control	24	2	10
	48	2	10
S@NSP	24	9	45
	48	15	75
S@HTL	24	9	45
	48	12	60
BB@NOE	24	3	15
	48	7	35

Sample	Time (Hrs)	Mortality (No. of organisms)	Mortality (%)
BB@M	24	13	65
	48	16	80
BG@N14	24	19	95
	48	20	100

72-Hour *Selenastrum Capricornutum* Test

June 2024 Results

The percentage algal growth rate in the undiluted test samples was compared to the control (**Figure *30***) where the control was placed at 100% as a reference. Samples with a growth rate of less than 80% (> 20% growth inhibition) compared to the control, are regarded as samples with a toxicity potential whereas the samples with 20% growth stimulation above the control indicate potential eutrophication. According to the results, there was a growth stimulation of 76,01 and 13,25% in BB@NOE and BB@M samples respectively. The highest eutrophication was obtained in sample BB@NOE which is the evidence of high pollution with nutrient-rich pollutants. BG@N14 was considered toxic as the algal growth rate was only 45.47% which is far less than the acceptable 80%. This means there was a growth inhibition of 54.53%.
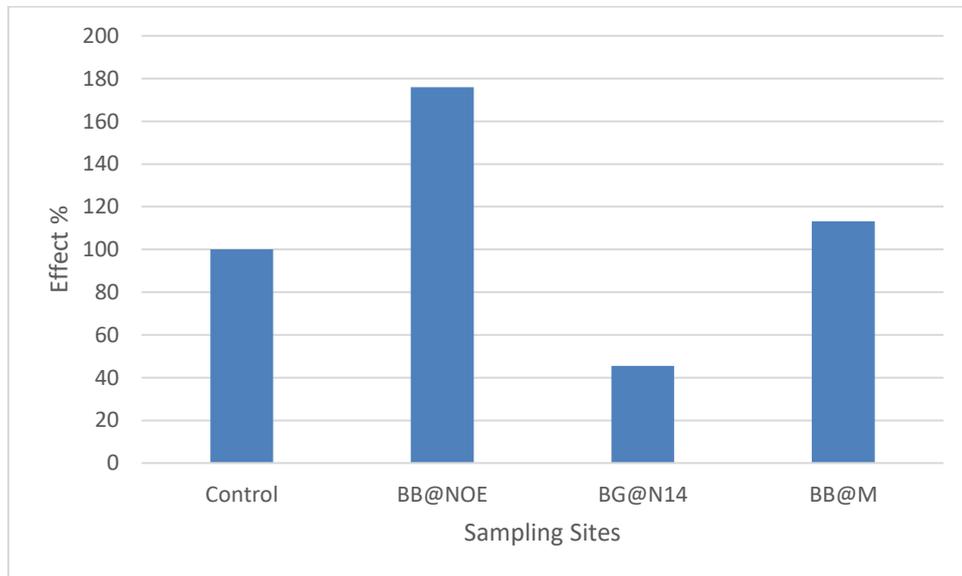
Figure 30   Algal growth rate in samples compared to control.

September 2024 Results

The percentage algal growth rate in the undiluted test samples was compared to the algal growth in the control (**Figure *31***) where the control was placed at 100% as a reference. Samples with a growth rate less than 80% (> 20% growth inhibition) compared to the control, are regarded as samples with a toxicity potential whereas the samples with 20% growth stimulation above the control indicate potential eutrophication. The results showed algal growth stimulation in all samples. The algal growth stimulations of 40.97, 85.83, 11.06, 45.79, and 76.79% were observed in samples BB@NOE, BB@M, S@HTL, S@NSP and BG@N14 respectively. Site S@HTL was the only site which was within acceptable conditions with at least 11.06% stimulation above the control. BB@M and BG@N14 were the sites with the highest stimulation followed by S@NSP and B@NOE respectively. These sites were highly polluted and showed a high accumulation of nutrients which resulted in increased eutrophication. These results have shown a similar trend with those from the V. fischeri test which also showed the high luminescence stimulation. This confirms and gives evidence that these rivers are highly polluted.
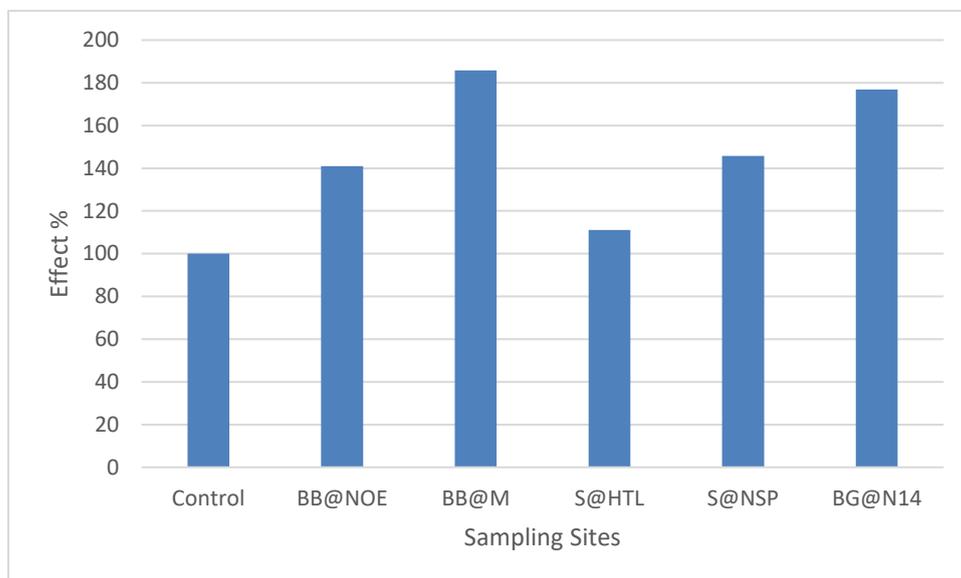
Figure 31 Algal growth rate in samples compared to control.

Physicochemical Parameters

The physical parameters are shown below in **Table *19*** and **Table *20***.

Table 19 The measured physicochemical parameters for June 2024 samples.

Parameters	Control 1	BB@NOE	BG@N14	BB@M
pH	6.9	6.32	6.71	6.55
Ec (µs/cm)	252	1267	774	1767
Temp (˚C)	16	11.7	11.3	12.4
DO (mg/L)	8.55	6.47	1.97	4.6

Table 20   The measured physicochemical parameters for September 2024 samples.

Parameters	Control 1	BB@M	BB@NOE	BG@N14
pH	6.65	6.55	6.23	6.67
Ec (µs/cm)	266	1824	1380	1052
Temp (˚C)	17.4	14.7	15.5	15.4
DO (mg/L)	9.78	2	3.33	1.46

6.2.3   Hazard Classification for Natural Waters

A risk/hazard class was determined by application of the DEEEP (Direct Estimation of Ecological Effect Potential) (DWAF, 2003; Slabbert, 2004) recommended protocols and the hazard classification system for natural waters (Persoone *et al.*, 2003). This hazard class equates to the level of acute or chronic risk posed by the water sample tested. A percentage effect (PE)[1] is determined for each of the tests in the battery of screening bioassays by measuring either immobility/mortality or inhibition/stimulation, depending on the type of test. The sample is then ranked into one of five classes (**Table 21**), based on either screening or definitive testing protocols.

Table 21   Hazard classification system for screening tests (Persoone et al., 2003).

Class	Description
CLASS I	No acute hazard – none of the tests shows toxic effect.
CLASS II	Slight acute hazard – a statistically significant percentage effect is reached in at least one test, but the effect level is below 50%.
CLASS III	Acute hazard – the 50 % effect level is reached or exceeded in at least one test, but the effect level is below 100%.
CLASS IV	High acute hazard – the 100% effect is reached in at least one test.
CLASS V	Very high acute hazard – the 100%percentage effect is reached in all the tests.

[1] Percentage effect: 10% effect = slight toxicity for daphnia and fish; 20% effect = slight toxicity for algae and bacteria; 50% and > effect = toxicity for all test organisms (bacteria, algae, daphnia, fish).

6.2.4   Discussion on River Health and Toxicity Assessment

The macroinvertebrates assessment indicates that the anthropogenic activities occurring in Bloubankspruit affect the ecosystem health leading to a decrease in taxa and total SASS5 scores. This is best evidenced by the E/F rating of past biomonitoring results. Effluent pollution has clearly led to the deterioration of the health of both sites on the Bloubankspruit with ASTP being at lowest compared to all sampling campaigns. The river water at Bloubankspruit River has been turbid in the past field trips which confirms the impact of recent flooding and probable effluent discharge into the system. However, there has been an improvement in ecological category of S@HTL and S@NSP compared to the previous results.

Toxicity Assessment

The DEEEP methods, as developed for South Africa and applied herein, are specifically aimed at assessing the ecological risks of complex surface water media (Slabbert *et al.*, 2004). Accordingly, the battery of tests used herein was aimed at indicating how the current pollution levels affect the aquatic ecosystem. This is critical to the decision-making process for intervention; the ecotoxicity data help to detect early perturbations in the aquatic ecosystem (Rodrigues *et al.*, 2021). In the current study, we observed no noticeable toxicity hazard from Bloubankspruit River samples for June from both *V. fischeri* and *D. magna* tests. However, the algal growth test showed some noticeable toxicity hazards in sample BG@N14 with potential eutrophication in sample BB@NOE. For all the September samples the toxicity hazard increased significantly. Skeerpoort River was at acute hazard classification with both sites (S@HTL and S@NSP) going beyond the 50% effect level for the *D. magna* test. Bloubankspruit River was classified as a high acute hazard with one site reaching 100% effect (BG@N14) and the other two sites were also above 50% effect (BB@NOE and BB@M). Both microalgae and *V. fischeri* tests showed potential eutrophication of greater than 20% in all river sites except for site S@HTL microalgae test. Bacterial and algal growth stimulations beyond acceptable limits are also signs of pollution.

The toxicity data revealed that all the river systems are highly polluted causing growth stimulation above permissible levels for bacteria and microalgae, especially in September samples. This showed greater eutrophication which is a sign of contamination with the nutrient-rich pollutants. The June samples showed no toxic effect for the tests such as *D. magna* acute immobilisation and *V. fischeri* growth inhibition/stimulation. The effects were only felt in the microalgae test with higher inhibition and stimulation in samples BG@N14 and BB@NOE respectively. September samples also showed a greater toxicity to the *D. magna* with mortality rates above 50% and even reaching 95 and 100% in some of the sites. Overall, the recent toxicity results have shown higher toxic effects in all the river systems with concomitant eutrophication. This necessitates the need and demand for some regulatory measures to lessen the matter. Knowing the potential sources of pollution in these river systems will be the key factor to monitor accordingly. It will be of much importance to further evaluate if the September season played a role in the observed high toxicity or if there was an increase in the pollution load (from the sources) ranging from June to September that had nothing to do with the change of the season. It could be that the pollutants are transported easily via runoffs to the rivers by the time it starts raining. The potential effects must be determined if the season had no effect.

7   DISCUSSION & CONCLUSIONS

The outcome of monitoring activities as documented in the 21st water resources *status quo* report indicate that the 2024 wet season experienced notably low rainfall, resulting in a significant decrease in discharge volumes compared to 2023. Rainfall at station HDS ranked in the 7th percentile of historical records, indicating a critical low that affects both surface and groundwater dynamics. The 2024 hydrological year recorded discharge volumes approximately 66% less than the previous year, reflecting a trend of reduced flow rates. Data limitations have affected the comprehensiveness of this assessment, particularly due to the absence of rainfall samples since January 2024. However, available rainwater chemistry data suggests consistent low salinity and acidity levels, with variations across different monitoring stations. In contrast, the previous hydrological year experienced unprecedented discharge levels due to flash floods, making the current declines notable.

Groundwater dynamics show stability in the southern segment, while slight declines in the central and northern areas have been observed. The Sterkfontein Cave lake has seen a significant decrease in water level since its peak in March 2023, highlighting the effects of climatic and environmental changes on regional water resources.

Hydrochemical and microbiological analyses indicate challenges regarding water quality. The Tweelopiespruit and Rietspruit show low pH values and elevated concentrations of sulphate and manganese. In contrast, the Blougatspruit and Bloubankspruit exhibit higher alkalinity but have been impacted by bacteriological contamination linked to municipal wastewater discharge. Elevated levels of E. coli and total coliform bacteria in surface waters indicate potential public health risks.

Variability in discharge and water quality among the springs is influenced by seasonal changes and extraction practices. Although some improvements have been noted due to mine water control measures, the presence of coliform bacteria in groundwater points to ongoing quality issues.

The interplay between these hydrological and environmental factors affects the current state of water resources and the preservation of fossil sites within the COHWHS. Altered water chemistry and contamination may impact the integrity of these paleontological resources.

In summary, the findings from this monitoring report validate the importance of the water resources monitoring program and the conceptual hydro(geo)logical model developed for the COHWHS. However, gaps in data hinder a comprehensive understanding of the hydrological system. It is essential to enhance data collection and continuous monitoring efforts to address the challenges posed by both natural variability and human activities affecting the region's water resources. Improved collaboration and resource allocation will be necessary to ensure the sustainability of water resources in the COHWHS.

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This report was prepared and reviewed by the undersigned.

Prepared: Reviewed:

_____   _____
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9   REFERENCES

Bredenkamp, D.B., van der Westhuizen, C., Wiegmans, F.E. and Kuhn, C.M. 1986. *Ground-water supply potential of dolomite compartments west of Krugersdorp.* Report GH3440. Vols. 1 & 2. Department of Water Affairs & Forestry. Pretoria. 81 pp.

Bugan, R.D.H., Mvandaba, V., Kapangaziwiri, E.; Hill, L. and McMillan, P.H. 2018. *Surface water and groundwater resources monitoring, Cradle of Humankind World Heritage Site, Gauteng Province, South Africa: Water resources status report for the period April to September 2018.* Report no. CSIR/NRE/WR/IR/2018/0084/C. Council for Scientific & Industrial Research. Pretoria. 40 pp.

Bugan, R.D.H., Mvandaba, V., Kapangaziwiri, E.; Hill, L. and McMillan, P.H. 2019. *Surface water and groundwater resources monitoring, Cradle of Humankind World Heritage Site, Gauteng Province, South Africa: Water resources status report for the period April to March 2019.* Report no. CSIR/NRE/WR/ER/2019/0022/B. Council for Scientific & Industrial Research. Pretoria. 40 pp.

Chakona, A. Phiri, C.C. Magadza, C.H.D. Brendonck, L. 2008. The Influence of habitat structure and flow permanence on macroinvertebrate assemblages in temporary rivers in north western Zimbabwe. *Hydrobiologia,* 607:199-209.

Clarke, A., MacNally, R., Bond, N. and Lake, P.S. 2008. Macroinvertebrate Diversity in Headwater Streams: A Review. *Freshwater Biology*, 53 (9): 1707-1721.

Cummins, K.W., Merritt, R.W. and Andrade, P.C.N. 2005. *The use of invertebrate functional groups to characterise ecosystem attributes in selected streams and rivers in south Brazil.* Studies on Neotropical Fauna and Environment. Vol. 40. No. 1. pp. 69-89.

Dallas, H.F. 2007. *River Health Programme: South African Scoring System (SASS) data interpretation guidelines (Draft report).* Prepared for the Institute of Natural Resources and the Resource Quality Services River Health, Department of Water Affairs and Forestry. Pretoria/Cape Town.

DEA 2016. *State of Conservation report for the fossil hominid sites of South Africa World Heritage Site (the Sterkfontein, Swartkrans, Kromdraai and environs component) (C 915 BIS).* Department of Environmental Affairs. 10 pp.

DEA 2018. *State of Conservation report to UNESCO on Decision 41 Com 7b.72 in regard to the Fossil Hominid Sites of South Africa World Heritage Site (The Sterkfontein, Swartkrans, Kromdraai and Environs Component) (C 915 BIS).* Department of Environmental Affairs. 37 pp.

Dickens, C.W.S. and Graham, P.M. 2002. *The South African Scoring System (SASS) Version 5 rapid bio assessment method for rivers.* African Journal of Aquatic Science. Vol. 27. No. 1. pp. 1-10.

Diković, S. and Koželj, A. 2015. Groundwater quality in changing hydrological conditions and comparison

with the results of long-term monitoring. In Hajna, N.Z, Ravbar, N., Rubinić, J. and Petrič, M. (Eds.), *Life and Water on Karst: Monitoring of transboundary water resources of Northern Istria*. pp 105-122. Ljubljana, Slovenia: Založba ZRC.

DWA 2011. *Mine water management in the Witwatersrand gold fields with special emphasis on acid mine drainage.* Report to the Inter-Ministerial Committee on Acid Mine Drainage. 128 pp.

Fourie, H.E., Thirion, C. and Weldon, C.W. 2014. *Do SASS5 scores vary with season in the South African Highveld? A case study on the Skeerpoort River, North West Province, South Africa.* African Journal of Aquatic Science. Vol. 39. No. 4. pp. 369-376.

Head, T., 2020. Watch: Gauteng floods – Johannesburg plunged underwater on Friday. *The South African*, 28 February 2020. Available: https://www.thesouthafrican.com/news/weather/gauteng-floods-johannesburg-weather-friday-28-february-traffic-latest/ (Accessed 13 May 2020)

Hill, L., McMillan, P. and Cheng, P. 2014. *An assessment of the biotic response in streams of the Western Basin that receive neutralised acid mine drainage.* Report no. CSIR/NRE/WR/IR/2014/0021/B. Pretoria. 26 pp.

Hobbs, P.J. (Ed.) 2011. *Situation assessment of the surface water and groundwater resource environments in the Cradle of Humankind World Heritage Site.* Report prepared for the Management Authority. Department of Economic Development. Gauteng Province. South Africa. 424 pp.

Hobbs, P.J. 2012. *Pilot implementation of a surface water and groundwater resources monitoring programme for the Cradle of Humankind World Heritage Site: Status report for the period April to September 2012.* Report no. CSIR/NRE/WR/ER/2012/0088/B. Council for Scientific & Industrial Research. Pretoria. 39 pp.

Hobbs, P.J. 2013a. *Pilot implementation of a surface water and groundwater resources monitoring programme for the Cradle of Humankind World Heritage Site: Situation assessment and status report for the period April 2012 to March 2013.* Report no. CSIR/NRE/WR/ER/2013/0023/B. Council for Scientific & Industrial Research. Pretoria. 48 pp.

Hobbs, P.J. 2013b. *Surface water and groundwater resources monitoring, Cradle of Humankind World Heritage Site, Gauteng Province, South Africa: Water resources status report for the period April to September 2013.* Report no. CSIR/NRE/WR/ER/2013/0083/A. Council for Scientific & Industrial Research. Pretoria. 47 pp.

Hobbs, P.J. 2014a. *Surface water and groundwater resources monitoring, Cradle of Humankind World Heritage Site, Gauteng Province, South Africa: Water resources status report for the period April 2013 to March 2014.* Report no. CSIR/NRE/WR/IR/2014/0049/A. Council for Scientific & Industrial Research. Pretoria. 42 pp.

Hobbs, P.J. 2014b. *Surface water and groundwater resources monitoring, Cradle of Humankind World Heritage Site, Gauteng Province, South Africa: Water resources status report for the period April*

to September 2014. Report no. CSIR/NRE/WR/ER/2014/0063/A. Council for Scientific & Industrial Research. Pretoria. 55 pp.

Hobbs, P.J. 2015a. *Surface water and groundwater resources monitoring, Cradle of Humankind World Heritage Site, Gauteng Province, South Africa: Water resources status report for the period April 2014 to March 2015.* Report no. CSIR/NRE/WR/ER/2015/0026/A. Council for Scientific & Industrial Research. Pretoria. 53 pp.

Hobbs, P.J. 2015b. *Surface water and groundwater resources monitoring, Cradle of Humankind World Heritage Site, Gauteng Province, South Africa: Water resources status report for the period April to September 2015.* Report no. CSIR/NRE/WR/ER/2015/0067/A. Council for Scientific & Industrial Research. Pretoria. 57 pp.

Hobbs, P.J. 2016a. *Surface water and groundwater resources monitoring, Cradle of Humankind World Heritage Site, Gauteng Province, South Africa: Water resources status report for the period April 2015 to March 2016.* Report no. CSIR/NRE/WR/ER/2016/0058/A. Council for Scientific & Industrial Research. Pretoria. 42 pp.

Hobbs, P.J. 2016b. *Surface water and groundwater resources monitoring, Cradle of Humankind World Heritage Site, Gauteng Province, South Africa: Water resources status report for the period April to September 2016.* Report no. CSIR/NRE/WR/ER/2016/0073/A. Council for Scientific & Industrial Research. Pretoria. 37 pp.

Hobbs, P.J. 2017a. *Surface water and groundwater resources monitoring, Cradle of Humankind World Heritage Site, Gauteng Province, South Africa: Water resources status report for the period April 2016 to March 2017.* Report no. CSIR/NRE/WR/ER/2017/0008/A. Council for Scientific & Industrial Research. Pretoria. 28 pp.

Hobbs, P.J. 2017b. *Surface water and groundwater resources monitoring, Cradle of Humankind World Heritage Site, Gauteng Province, South Africa: Water resources status report for the period April to September 2017.* Report no. CSIR/NRE/WR/ER/2017/0072/A. Council for Scientific & Industrial Research. Pretoria. 26 pp.

Hobbs, P.J. 2017c. *TDS load contribution from acid mine drainage to Hartbeespoort Dam, South Africa.* Water SA. Vol 43. No. 4. 12 pp.

Hobbs, P.J. and de Meillon, N. 2017. *Hydrogeology of the Sterkfontein Cave System, Cradle of Humankind, South Africa.* South African Journal of Geology. Vol 120. No. 3. pp. 403-420.

Hobbs, P.J., Hill, L. and McMillan, P.H. 2018. *Surface water and groundwater resources monitoring, Cradle of Humankind World Heritage Site, Gauteng Province, South Africa: Water resources status report for the period April to September 2018.* Report no. CSIR/NRE/WR/ER/2018/0010/A. Council for Scientific & Industrial Research. Pretoria. 40 pp.

Karaouzas, I. Gritzalis, K. Skoulikidis, N. 2007. Land use effects on macroinvertebrates assemblages and stream quality along an agricultural river basin. *Environmental Bulletin* **16**(6):645-653.

Krugersdorp News, 9 December 2022. Flooding Havoc Across the West Rand: Places to Avoid in Krugersdorp. Accessed on 19 May 2023 at https://krugersdorpnews.co.za/495815/flooding-havoc-across-the-west-rand-places-to-avoid-in-krugersdorp/.

McMillan, P.H. 1998. *An integrated habitat assessment system for the rapid biological assessment of rivers and streams.* Internal STEP report no. ENV-P-I 98088. CSIR. 37 pp.

Mvandaba, V. and Kapangaziwiri, E. 2019. *Surface Water and Groundwater Resources Monitoring, Cradle of Humankind World Heritage Site, Gauteng Province, South Africa.* Progress Report No.27, GT/GDED/092/2017. CSIR, Pretoria.

Mvandaba, V., Kapangaziwiri, E. and Shadung, J. 2019. *Surface water and groundwater resources monitoring, Cradle of Humankind World Heritage Site, Gauteng Province, South Africa: Water resources status report for the period April to September 2019.* Council for Scientific & Industrial Research. Pretoria. 77 pp.

Mvandaba, V., Kapangaziwiri, E. and Shadung, J. 2020a. *Surface water and groundwater resources monitoring, Cradle of Humankind World Heritage Site, Gauteng Province, South Africa: Water resources status report for the period April 2019 to March 2020.* Council for Scientific & Industrial Research. Pretoria. 77 pp.

Mvandaba, V., Kapangaziwiri, E. and Shadung, J. 2020b. *Surface water and groundwater resources monitoring, Cradle of Humankind World Heritage Site, Gauteng Province, South Africa: Water resources status report for the period April 2020 to September 2020.* Council for Scientific & Industrial Research. Pretoria. 77 pp.

Nkanjeni, U. 2019. 'Dramatic scenes of chaos in parts of Gauteng after flooding', *Times Live*, 10 December. Available at: https://www.timeslive.co.za/news/south-africa/2019-12-10-dramatic-scenes-of-chaos-in-parts-of-gauteng-after-flooding/. (Accessed 13 May 2020).

Ramaphosa, C. 2020. *Update on the Coronavirus COVID-19 lockdown* (Transcript). Available: https://www.gov.za/speeches/president-cyril-ramaphosa-update-coronavirus-covid-19-lockdown-30-mar-2020-0000 (Accessed 27 May 2020).

SANS 2015a. *South African National Standard (SANS) 241-1. Drinking water. Part 1: Microbiological, physical, aesthetic and chemical determinands.* Edition 2. Standards South Africa. Pretoria. 14 pp.

SANS 2015b. *South African National Standard (SANS) 241-2. Drinking water. Part 2: Application of SANS 241-1.* Edition 2. Standards South Africa. Pretoria. 14 pp.

SAWS (South African Weather Services), 2019. *Heavy downpours expected over eastern, northern and central parts in South Africa from tonight until Thursday, 5 December 2019*. Media Release, 3 December 2019. Available at: https://www.weathersa.co.za/Documents/Corporate/Medrel3Dec2019%20.pdf (Accessed 13 May 2020).

Sheik, C.S. Mitchell, T.W. Rizvi, F.Z. Rehman, Y. Faisal, M. Hasnain, S. McInerney, M.J. Krumholtz, L.R. 2012. Exposure of soil microbial communities to chromium and arsenic alters their diversity and structure. Available: https://doi.org/10.1371/journal.pone.0040059 (Accessed 10 October 2020).

Slabbert, L. 2004. *Methods for direct estimation of ecological effect potential (DEEEP).* Report no.: 1313/1/04. Water Research Commission, Pretoria. 100 pp.

Stumpf, S., Valentine-Darby, P. and Gwilliam, E. 2009. *NPS inventory and monitoring program.* Aquatic Macroinvertebrates – Ecological role. US National Park Service.

USEPA 2002. *Methods for measuring the acute toxicity of effluents and receiving waters to freshwater and marine organisms.* Fifth Edition. Report no.: EPA-821-R-02-012. U.S. Environmental Protection Agency. USA.

ANNEXURE A

DESCRIPTION OF THE AQUATIC BIOMONITORING SURVEY SITES

A.1   GENERAL

All four sites are located Western Bankenveld ecoregion. Site S@HTL, however, is considered a transitional location as it is located close to the boundary with the Bushveld Basin ecoregion to the north.

A.2   Site S@HTL

This is located on the Skeerpoort River approximately 50 metres downstream of a small trout farm. Although much of the surrounding area is natural and undisturbed, several riparian trees were observed to be chopped and cut down. The sampling area comprises a pool of slow-moving/still water, leading to a narrower region of faster-flowing riffles. Most habitats are well represented, although there was a lack of sandy areas.

Figure A.1: Downstream site S@HTL on the Skeerpoort River

The macroinvertebrate family diversity for this site is summarised in **Table A.1** below.

Table A.1: Macroinvertebrate families present at site S@HTL

Macroinvertebrate families	13/02/2018	17/10/2018	25/03/2019	16/09/2019	02/03/2020	15/09/2020	15/03/2023
Turbellaria	40	3	1				
Oligochaeta		1	2				
Potamonautidae	3	3	12	11	3	7	
Hydracarina	40	1	4				
Baetidae	80	240	80	109	88	120	
Caenidae	30	20	6	3		11	
Prosopistomatidae					8		
Teloganodidae	2		2	12			
Heptageniidae	10	40	30				
Leptophlebiidae	240	100	60				
Tricorythidae	1		4				
Chlorocyphidae	20	20	15				
Coenagrionidae		2		4	4	4	
Lestidae	3	1	6				
Aeshnidae	2	15	20		1	5	
Gomphidae	1	2	2				
Libellulidae	1		1	3		1	
Pyralidae			1				
Belostomatidae	30	2	60				
Corixidae	40	4	2			1	
Gerriae	2				10		
Naucoridae			1				
Nepidae	2	6					
Notonectidae			30		9	120	
Pleidae	20	15	30	101	180		
Veliidae	40	1	2				
Hydropsychidae	6	2	1	80	10		
Philopotamidae		2	30				
Dytiscidae		3				6	
Psychomyiidae					7		
Elmidae	20	8	10	4			
Gyrinidae	2	1					
Libellulidae	40	20	10	4			
Ceratopogogonidae		2		3	7	4	
Athericidae	5	6					
Chironomidae			3	20	44	4	
Dixidae	2	2					
Simuliidae	1	1	12		28	4	
Tabanidae		1				4	
Tipulidae						20	
Ancylidae							
Planorbinae*							

A.3   Site S@NSp

This is located on a spring-fed tributary (the Groot Spruit) of the Skeerpoort River some 4000 m upstream from site S@HTL. The survey site itself is located ~120 m downstream of the Nouklip Spring, and would therefore count as a headwater site. The habitat is varied and adequate, and large areas of the riverbed are sandy. The surrounding area is largely undisturbed, natural vegetation. The   macroinvertebrate family diversity for this site is summarised in **Table A.2**.

Figure A.2: Upstream site S@NSp on the Skeerpoort River

Table A.2: Macroinvertebrate families present at site S@NSp

Macroinvertebrate families	27/02/2018	26/09/2018	26/03/2019	16/09/2019	02/03/2020	14/09/2020	13/03/2023
Oligochaeta	1		1		45		
Potamonautidae	8		8		5	1	1
Atyidae					8		
Palaemonidae					120		
Hydracarina	1	4		3			
Plecoptera					1		
Baetidae	40	30	6	5	10	29	36
Notonemouridae					1		
Caenidae	6	4	30	3		20	
Teloganodidae				5	1		
Leptophlebiidae		10					
Tricorythidae		6					
Chlorocyphidae		1	1				
Calopterygidae					1		
Coenagrionidae	12		3		1		
Aeshnidae	1			12	12		
Gomphidae	16	20	50			14	
Pyralidae	1		1				
Libellulidae					1		
Corixidae	5	100	20			1	
Gerridae	5			4	1	1	8
Hydrometridae					1	14	
Naucoridae			12				1
Notonectidae				3	1		
Pleidae	1	2	6	107			
Veliidae	10	15	10	6	88	11	
Ecnomidae					7		
Hydropsychidae		30	3		9		
Psychmyiidae				3		3	
Gyrinidae	12						
Psephenidae	6	1	2				
Ceratopogonidae			2				
Chironomidae	3			6	8	4	6
Dixidae					8	9	
Simuliidae		12		12	9		
Tabanidae	1		3			9	
Tipulidae		2				110	
Ancylidae	1		2				
Planorbinae*		1					
Hydraenidae							5

A.4   Site BB@M

The upstream site on the Bloubankspruit was originally immediately downstream of the causeway over the stream at Makiti. Although there is excellent habitat abundance and diversity, concern exists for the impact of the causeway and culverts on the morphology of the site.   The site has therefore been moved ~350 m downstream where more natural conditions prevail, but maintains its position upstream of the Zwartkrans Spring, i.e. located upstream of the first major groundwater discharge into the Bloubankspruit. A significant difference between the 'old' and the 'new' sites is the abundance of a sandy substrate and absence of riffles at the 'old' site, compared to the abundance of riffles and moderate sandy substrate at the 'new' site. The macroinvertebrate family diversity for this site is summarised in **Table A.3** below.

Figure A.3:   Site BB@M on the Bloubankspruit

Table A.3: Macroinvertebrate families present at site BB@M.

BB@M	13/02/2018	25/09/2018	25/03/2019	17/09/2019	02/03/2020	16/09/2020	06/12/2022	15/03/2023
Turbellaria		1	8	4	15	44	8	2
Leeches	1		1				1	
Oligochaeta		1		6	2		5	1
Crustacea	3	1	2	6				
Potamonautidae	40	40		8				
Baetidae		40	10	12	19		10	
Coenagrionidae		10		3			11	8
Aeshnidae		8	3					
Gomphidae		1	6					
Corixidae	30							
Gerriade	4	3	12					
Pleidae			1	7				
Ecnomidae	40	100	20	18				
Veliidae	1							
Hydropsychidae	100	200	300	55	38			
Psychomiidae			3	15				
Gyrinidae			1					
Ceratopogonidae				161	120	1	1	
Chironomidae				33	219	330	450	460
Culicidae					180			
Simuliidae				29	5		370	280
Physidae					7	7	10	
Ancylidae				4				
Coelenterata								
Hirunidae								
Libellulidae							1	
Belostomatidae							1	
Dytiscidae							1	

A.5   Site BB@NOE

Site BB@NOE is located on the Bloubankspruit ~7400 m downstream of site BB@M. This position places it downstream of the last major groundwater discharge (that from the Kromdraai and Plover's Lake springs) into the Bloubankspruit. This site appears to be turbid, even when the upstream site BB@M is clear. There is a trout farm upstream of the site. The habitat diversity at the site is far less compared to the upstream site and is mostly bedrock and large stones. There is little sand, and the overhanging vegetation is often limited. The macroinvertebrate family diversity for this site is summarised in **Table A.4**.

Figure A.4:   Site BB@NOE on the Bloubankspruit.

Table A.4:   Macroinvertebrate families present at site BB@NOE.

BB@NOE	13/02/2018	25/09/2018	25/03/2019	17/09/2019	16/09/2020
Turbellaria		1		4	33
Annelida					4
Leeches		1			
Oligochaeta	2			6	6
Crustacea	2	1	3	6	
Potamonautidae	80	40	4	8	3
Baetidae	10	40	30	12	24
Coenagrionidae		10		3	
Aeshnidae		8	25		
Gomphidae		1			
Corixidae	2				
Gerriade	2				
Pleidae			15	7	
Ecnomidae	40		1	18	
Veliidae	3	3			
Hydropsychidae	2			55	6
Psychomiidae	40	100	40	15	
Gyrinidae	1				6
Ceratopogonidae	50	200	60	161	3
Chironomidae				33	220
Culicidae					
Simuliidae				29	
Syrphidae					17
Ancylidae				4	1

ANNEXURE B

MATERIALS AND METHODS

Toxicity assays

A battery of four screening toxicity assays was conducted on each sample according to standard procedures, under laboratory conditions (**Table B.1, B.2, B.3 and B.4**):

- 15-minute *Vibrio fischeri* (bacterium)
- 72-hour *Selenastrum capricornutum* (algae)
- 48-hour *Daphnia magna* (water flea)

The assays were performed to assess the toxicity potential of the test samples by assessing the response of the exposed test organisms. The test organisms were applied directly to the test samples (screening assays), except in the case of the algal assay and bacterium assay where samples were filtered through a 45 µm filter prior to testing. When a 50% or more toxicity effect was detected, definitive tests were conducted.

15-minute *Vibrio fischeri* screening assay

Table B.1 Summary of test conditions and test acceptability criteria for the bacterium *Vibrio fischeri* growth tests (ISO, 1998).

Parameter	Condition maintained during test
Test type	Static non-renewal
Volume of test sample	0.5 mℓ
Exposure period	15 and /or 30 minutes
Number of replicate chambers	2
Measurement equipment	Luminoskan Sirius Luminometer
Adjustment	20% salinity adjustment
Effects measured and interpretation	Screening test - % Luminescence inhibition (-) / stimulation (+) relative to the Control; Inhibition / Stimulation of ≥20% over control indicates toxic activity; Definitive test - EC20 and EC50 –values

72 / 96-hour *Selenastrum capricornutum* screening assay

Table B.2: Summary of test conditions and test acceptability criteria for the *Selenastrum capricornutum* growth inhibition tests – microplate assay for effluents and receiving waters (Slabbert, 2004).

Parameter	Condition maintained during test
Test type	Static non-renewal
Temperature	24± 2° C
Light quality	"Cool white" fluorescent lighting
Light intensity	4306 lux
Photoperiod	Continues
Volume of test sample	180 µl (plus 20 µl algal inoculum and medium)
Age of algal culture	4 to 6 days
Inoculum size	200 000 cells/mL
Number of replicate chambers	5
Shaking rate:	100 cpm continuous
Aeration	None
Dilution water	Algal stock culture media
Test duration	72 to 96 hours
Effects measured	Percentage inhibition or stimulation of growth compared to Control
Interpretation	Inhibition of ≥20% over Control indicates toxic activity, while growth of ≥20% over controls indicates stimulation

48-hour *Daphnia magna* screening assay

Table B.3 Summary of test conditions and test acceptability criteria for *Daphnia magna* acute toxicity tests with effluents and receiving waters (Slabbert, 2004).

Summary of toxicity test	
Test system	*Daphnia* test
Test species	*Daphnia magna*
Age of test organisms	Less than 48h old
Trophic level	Grazer
Toxicity level	Acute toxicity
Test procedure	USEPA, 2002
Summary of test conditions for the Daphnia magna acute toxicity test	
Test type	Static-renewal
Water temperature	20 ºC ± 1 ºC; or 25 ºC ± 1 ºC
Light quality	Ambient laboratory illumination
Photoperiod	8 hours dark: 16 hours light
Feeding regime	Feed algae and commercial fish flakes while in holding prior to test
Aeration	None
Size of test chamber	50 mL
Volume of test sample	25 mL
Number of test organisms per chamber	5
Number of replicate chambers	4
Total number of test organisms per sample	20
Control and dilution water	Moderately hard, reconstituted water
Test duration	48 hours
Effect measured	Percentage lethality (no movement on gentle prodding), calculated in relation to control
Test acceptability	90% or greater survival in control
Interpretation	Lethality >10% indicates toxicity, provided that control lethality is ≤10%

Phytotoxicity test

The toxicity classification of the sediment and pore water samples is generally performed using direct-contact tests Phytotoxkit (sediment) and Phytotestkit (pore water). In all tests the pore water samples were tested at one concentration without dilution. Sediment samples were not used in this round of analysis due to insufficient sampling of sediment as sediment tox training took place after the sampling trip, therefore phytotestkit (pore water samples) was conducted instead of Phytotoxkit (sediment samples).

Phytotoxkit and phytotestkit are generally applied for the sediment and pore water toxicity classification using three test plant seeds: *Sorghum saccharatum, Lepidium sativum* and *Sinapis alba*. The measures parameters were inhibition of seed germination and root lemgth inhibition in the tested sediment/pore water in comparison with the control sediment/redistilled water. The test was conducted in accordance with the procedure recommended by the manufacturer (Phytotoxkit, 2004). The studied sediment samples (90 cm^3) were placed on test plates (21 15.5 0.8 cm). In the Phytotestkit assay the lower compartment of the test plate is not filled with soil, but with a foam pad and thick filter paper which is subsequently soaked with the chemical compound under analysis. This alternative test procedure allows you to determine any significant visible effect of chemical compounds on plants, without adding the chemical(s) to a soil substrate. 20 cm^3 of the pore water was slowly spread over the entire surface of the white filter paper in order to hydrate the filter paper completely. The bottom part of the test plates with sediment/pore water samples were covered by a black filter paper, and ten test seeds were placed in a row at 1 cm below the middle ridge of the plate. The plates prepared in this way were incubated in a horizontal position at 25 ^{o}C in darkness for 72 h. A photo of the test plate was then taken with a digital camera and transferred to a computer. Root lengths were subsequently measured using the "Image Tools" image analysis program. The test was replicated three times for each test plant. The percent inhibition of seed germination (IG) and inhibition of root growth (IR) for the plant were calculated.

Ostracod test exposure

Ostracod exposure tests were conducted as 6 replicates per site sample and 1 control per sample by using reference sediment (consisting of washed marine sediment less than 2 mm in size) according to the standard operating procedures of the test kit (Ostracodtoxkit F, 2001) and the ISO (2012) method. Ostracod neonates were exposed to test sediments (6 days in darkness at 25°C ± 2°C). Upon completion of the test period, all surviving ostracods were collected and photographs were taken with a compound microscope (with a built-in digital camera) using a micrometre cover slip as a reference point. Using the UTHSCSA ImageTool (Version 3) software, growth inhibition of surviving ostracods exposed to test sediments was determined in relation to the control exposure. Mortality data were also noted. Data from the two sediment bioassays were analysed using Microsoft Excel.

Hazard classification for natural waters

A risk/hazard class was determined by application of the DEEEP (Direct Estimation of Ecological Effect Potential) (DWAF, 2003; Slabbert, 2004) recommended protocols and the hazard classification system for natural waters (Persoone *et al.*, 2003). This hazard class equates to the level of acute or chronic risk posed by the water sample tested. A percentage effect (PE)[1] is determined for each of the tests in the battery of screening bioassays by measuring either immobility/mortality or inhibition/stimulation, depending on the type of test. The sample is then ranked into one of five classes, based on either screening or definitive testing protocols.

Table B.4   Hazard classification system for screening tests (Persoone *et al.*, 2003)

Class	Description
CLASS I	No acute hazard – none of the tests shows toxic effect.
CLASS II	Slight acute hazard – a statistically significant percentage effect is reached in at least one test, but the effect level is below 50%.
CLASS III	Acute hazard – the 50 % effect level is reached or exceeded in at least one test, but the effect level is below 100%.
CLASS IV	High acute hazard – the 100% effect is reached in at least one test.
CLASS V	Very high acute hazard – the 100%percentage effect is reached in all the tests.

[1] Percentage effect: 10% effect = slight toxicity for daphnia and fish; 20% effect = slight toxicity for algae and bacteria; 50% and > effect = toxicity for all test organisms (bacteria, algae, daphnia, fish).

Table B.5 Physicochemical parameters per sample measured at the start and end of the tests (March 2023).

Sites	Time	Temperature	pH	EC	Oxygen
Control	0	21	7.99	301	7.66
	48	20.9	7.61	298	6.47
S@HTL	0	21.4	7.44	409	7.82
	48	21.4	7.18	425	7.88
S@HTC	0	20.9	7.42	352	7.8
	48	21.4	7.48	347	7.9
BB@M	0	21.8	6.99	1489	7.45
	48	20.7	7.1	1477	7.19
BG@N14	0	21.5	6.54	1457	7.69
	48	21.9	6.98	1449	7.18
BB@NOE	0	21.1	7.31	1266	7.45
	48	20.9	7.39	1301	7.22

PREVIOUS TOXICITY TESTING RESULTS

15-minute *Vibrio fischeri* test (September 2022)

Physical parameters measured at the start and end of each test with a hand-held Hach HQ 40D multi parameter meter, are summarised in **ANNEXURE B**. 15-minutes for the *V. fischeri* luminescence inhibition (-) / stimulation (+) test after a 15-minute exposure period were as follows: S@HTL test sample: 3.58%; S@NSP test sample: 5.95%; BB@M test sample: -14.29% and B@NOE test sample: -7.72%. Inhibition of > 20% indicates toxicity and stimulation of > 20% indicates potential eutrophication. In all the sites, there was no indication of toxicity or potential eutrophication; However there was contrasting results on both rivers. There was inhibition at Bloubank Spruit with the highest inhibition occurring in site BB@M while at Skeerpoort River sites there was minimal stimulation. Tests were accepted as the% CV was > 3%.

48-hour *Daphnia magna* test (September 2022)

Error! Reference source not found. summarises the results of D. magna exposed to the undiluted test s amples S@HTL, S@NSP, BB@M and B@NOE. The tests were accepted as no mortality (≤ 10%) was observed in the Control. At the end of the exposure period (48 hours), the highest mortality was found in sample BB@M and BB@NOE of which the mortality percentage was 30% and 20% respectively. The mortality percentage remained low at Skeerpoort Spruit samples.

Sample	Time (Hrs)	Mortality (No. of organisms)	Mortality (%)
Control	24	0	0
	48	0	0
S@NSP	24	1	5
	48	1	5
S@HTL	24	0	0
	48	1	5
BB@NOE	24	1	5
	48	4	20
BB@M	24	2	10
	48	6	30

72-hour Selenastrum capricornutum test (September 2022)

The percentage algal growth rate in the undiluted test samples was compared to the algal growth rate in the Control (**Figure 32**). Samples with a growth rate less than 80% (> 20% growth inhibition) compared to the Control, are regarded as samples with a toxicity potential. According to the results, samples at BB@M and S@HTL were potentially considered toxic as growth rate of less than 80% was detected. This was significant in BB@M as the growth rate was 64.37% compared to Control.

Algal growth rate in samples compared to control
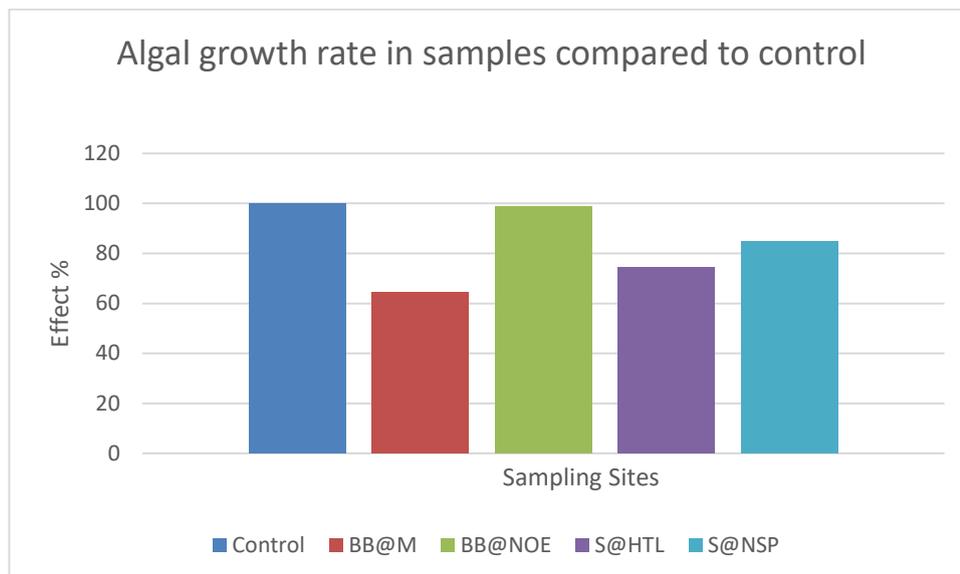
V. fischeri test (September 2020)

Physical parameters measured at the start and end of each test with a hand-held Hach HQ 40D multi parameter meter, are summarised in **ANNEXURE B**. 15-minutes for the _V. fischeri_ luminescence inhibition (-) / stimulation (+) test after a 15-minute exposure period were as follows: S@HTL test sample: 6.45%; S@NSP test sample: 1.98%; BB@M test sample: 29.06% and B@NOE test sample: 21.44%. Inhibition of >20% indicates toxicity and stimulation of > 20% indicates potential eutrophication. In all the sites, there was an indication of potential eutrophication in two sites namely; BB@M and B@NOE as stimulation exceeded 20%. Tests were accepted as the% CV was > 3%.

V. fischeri test (March 2020)

15-minutes for the V. fischeri luminescence inhibition (-) / stimulation (+) test after a 15-minute exposure period were as follows: S@HTL test sample: 4.36%; S@NSP test sample: 0.98%; BB@M test sample: 24.06% and B@NOE test sample: 20.18%. Inhibition of > 20% indicates toxicity and stimulation of > 20% indicates potential eutrophication. In all the sites, there was an indication of potential eutrophication in two sites namely; BB@M and B@NOE as stimulation exceeded 20%. Tests were accepted as the% CV was > 3%.

S. Capricornatum test (March 2020)

Algal growth rate in samples compared to control
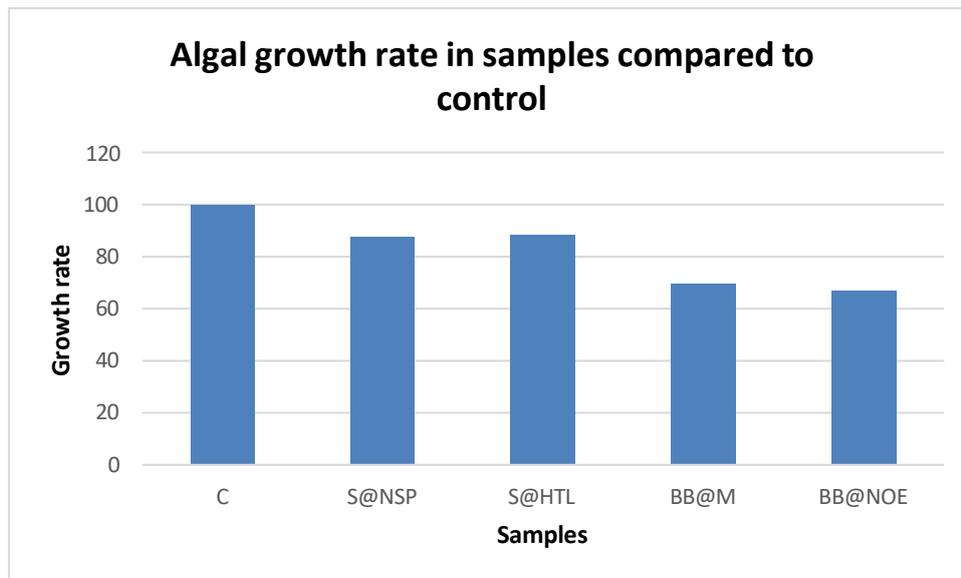
D. magna test

Table 16 B.2a Results of the *D. Magna* screening assays expressed as percentage mortality after 24 and 48 hours (September 2019).

Sample	Time (hrs)	Mortality (No. of organisms)	Mortality (%)
CONTROL	24	0	0
	48	0	0
S@NSp	24	0	0
	48	5	25
S@HTL	24	0	0
	48	0	0
BB@NOE	24	0	0
	48	0	0
BB@M	24	0	0
	48	0	0

Table B.2b Results of the *D. magna* screening assays expressed as per cent mortality after 24 and 48 hours (March 2019).

Sample	Time (hrs)	Mortality (No. of organisms)	Mortality (%)
CONTROL	24	0	0
	48	0	0
S@NSp	24	0	0
	48	0	0
S@HTL	24	0	0
	48	0	0
BB@NOE	24	0	0
	48	0	0
BB@M	24	0	0
	48	0	0

Table B.2c Results of the *D. magna* screening assays expressed as per cent mortality after 24 and 48 hours (September 2018).

Sample	Time (hrs)	Mortality (No. of organisms)	Mortality (%)
CONTROL	24	0	0
	48	1	5
N@NSp	24	0	0
	48	0	0
HTC (S@HTL)	24	1	0
	48	1	5
BB@NOE	24	1	5
	48	3	15
BB@M	24	1	5
	48	1	5

Table B.2d Results of the *D. magna* screening assays expressed as per cent mortality after 24 and 48 hours (February 2018)

Sample	Time (hrs)	Mortality (No. of organisms)	Mortality (%)
CONTROL	24	0	0
	48	0	0
HTC (S@HTL)	24	0	0
	48	0	0
BB@NOE	24	1	5
	48	3	15
BB@M	24	0	0
	48	1	5

Table 17 B.3b. Physicochemical parameters per sample measured at the start and end of the tests (September 2019).

Sample	Time (hrs)	Temperature (°C)	pH	SEC (mS/m)	Dissolved oxygen (mg/L)
CONTROL	0	19.3	7.04	254	7.71
	48	20.0	7.48	349	7.37
S@NSP	0	19.6	7.48	405	7.79
	48	20.0	7.78	438	7.28
S@HTL	0	19.5	7.40	340	8.30
	48	20.1	7.64	426	7.12
BB@NOE	0	19.6	7.10	1204	7.31
	48	20.2	7.40	1464	6.94
BB@M	0	19.7	6.93	1795	6.87
	48	20.1	7.01	2092	6.73

Table B.3a Physicochemical parameters per sample measured at the start and end of the tests (March 2019).

Sample	Time (hrs)	Temperature (°C)	pH	SEC (mS/m)	Dissolved oxygen (mg/L)
CONTROL	0	19.3	7.04	254	7.71
	48	20.0	7.48	349	7.37
S@NSP	0	19.6	7.48	405	7.79
	48	20.0	7.78	438	7.28
S@HTL	0	19.5	7.40	340	8.30
	48	20.1	7.64	426	7.12
BB@NOE	0	19.6	7.10	1204	7.31
	48	20.2	7.40	1464	6.94
BB@M	0	19.7	6.93	1795	6.87
	48	20.1	7.01	2092	6.73

Table B.3b. Physicochemical parameters per sample measured at the start and end of the tests (September 2018).

Sample	Time (hrs)	Temperature (°C)	pH	SEC (mS/m)	Dissolved oxygen (mg/L)
CONTROL	0	20.0	8.21	25.5	7.52
	48	20.0	7.78	36.7.7	7.47
N@NSP	0	20.0	7.99	36.4	8.31
	48	20.1	8.41	45.4	7.43
HTC (S@HTL)	0	20.0	7.63	35.0	7.62
	48	20.0	8.08	33.6	7.31
BB@NOE	0	20.0	7.93	136.4	8.73
	48	20.0	7.96	148.2	7.45
BB@M	0	20.0	6.67	184.4	7.61
	48	20.0	6.96	209.4	7.33

Table C.3c. Physicochemical parameters per sample measured at the start and end of the tests (February 2018).

Sample	Time (hrs)	Temperature (°C)	pH	SEC (mS/m)	Dissolved oxygen (mg/L)
CONTROL	0	20.0	8.10	21.3	7.24
	48	20.1	8.01	23.7	7.04
HTC (S@HTL)	0	20.1	8.31	30.8	7.59
	48	20.0	7.73	43.8	6.05
BB@NOE	0	20.2	7.96	124.7	6.73
	48	20.0	8.22	138.7	6.35
BB@M	0	20.2	7.72	187.2	6.68
	48	20.1	7.76	201.9	6.66