FAUNAL, FLORAL, WETLAND AND AQUATIC ASSESSMENT AS PART OF THE ENVIRONMENTAL ASSESSMENT AND AUTHORISATION PROCESS FOR THE PROPOSED THARISA MINE DEVELOPMENT PROJECT, NORTH WEST PROVINCE

Prepared for

SLR Consulting (Africa) (Pty) Ltd.

2013

SECTION E – Aquatic Assessment

Prepared by:	**Scientific Aquatic Services**
Report author	**S. van Staden (Pr. Sci. Nat)**
	M. Hanekom
	A. Mileson
Report Reference:	**SAS 213199**
Date:	**November 2013**

Scientific Aquatic Services CC
CC Reg No 2003/078943/23
Vat Reg. No. 4020235273
91 Geldenhuis Rd
Malvern East, Ext 1

Tel: 011 616 7893
Fax: 011 615 4106
E-mail: admin@sasenvironmental.co.za

TABLE OF CONTENTS

List of Figures

List of Tables

1 INTRODUCTION

1.1 Background

Scientific Aquatic Services (SAS) was appointed to conduct a faunal, floral, wetland and aquatic ecological assessment as part of the environmental assessment and authorisation process for the proposed mine developments related to the Tharisa Mine, hereafter referred to as the “subject property” (Section A: Figures 2 & 3). The subject property is situated immediately to the north of the N4 roadway within the North West Province. The town of Marikana is situated approximately 3km to the north, and the towns of Lapologang, Tsilong Village and Silver City (formerly Mmaditlhokwa Village) are located approximately 3km to the west, while Rustenburg is located 30km to the northwest. Existing infrastructure within the Mining Rights Area (MRA) include two open pit areas, various waste rock dumps, a plant and office area, return and raw water dams, a storm water dam, a sewage treatment plant (STP) and a Run-of-Mine (ROM) pad, whilst the proposed development, which forms the focus of this study, includes the expansion of open pit and waste rock dump areas.

This aquatic study includes previous historical aquatic reports which are available for the Sterkstroom River systems. The latter are the watercourses which could potentially be affected by the Tharisa mining subject property. Historical baseline and biomonitoring assessments for Tharisa Mine was conducted by Natural Scientific Services (NSS). These resulted in a pre-construction baseline aquatic assessment report (2008) and operational biomonitoring reports for years 2010 and 2011. The current biomonitoring report was compiled by Clean Stream Biological Services CC., based on an assessment undertaken in August 2013. The previous historical reports are presented in Table 1 below. Not all reports were available at the time of current report compilation.

Table 1: Historical aquatic reports associated with the Tharisa Mine relating to the Sterkstroom River catchment.

Date	Aquatic report reference	Specialist name	Reference	River catchment
2008	**1211 March 2008**	Natural Scientific Services	NSS 2008	Sterkstroom River
2010	**1486 September 2010**	Natural Scientific Services	NSS 2010	Sterkstroom River
2011	**1486 June 2011**	Natural Scientific Services	NSS 2011	Sterkstroom River
2013	**TM/A/13**	Clean Stream	CS 2013	Sterkstroom River

The previous historical aquatic reports include aquatic ecological assessments in which both biological (habitat assessment indices, fish, riparian vegetation and macro-invertebrates) and toxicological assessment of the aquatic resources in and associated with the subject property was undertaken.

1.2 Legislative requirements

1.2.1 National Environmental Management Act, 1998

- The National Environmental Management Act (Act 107 of 1998) and the associated Regulations (Listing No R. 544, No R. 545 and R. 546) as amended in June 2010, states that prior to any development taking place within a wetland or riparian area, an environmental authorisation process needs to be followed. This could follow either the Basic Assessment process or the EIA process depending on the nature of the activity and scale of the impact.

1.2.2 National Water Act, 1998

- The National Water Act (Act 36 of 1998) recognises that the entire ecosystem and not just the water itself in any given water resource constitutes the resource and as such needs to be conserved.
- No activity may therefore take place within a water course unless it is authorised by DWA.
- Any area within a wetland or riparian zone is therefore excluded from development unless authorisation is obtained from DWA in terms of Section 21.

1.2.3 GN 704 – Regulations on use of water for mining and related activities aimed at the protection of water resources, 1999

- These Regulations, forming part of the National Water Act, were put in place in order to prevent the pollution of water resources and protect water resources in areas where mining activity is taking place from impacts generally associated with mining.

2 METHOD OF ASSESSMENT USING HISTORICAL DATA

A historical literature study and analyses of existing aquatic biomonitoring data was conducted in order to: 1) define the Present Ecological State (PES) as well as spatial and temporal trends of the study areas and 2) capture comprehensive baseline data with respect to the aquatic ecology prior to the proposed Tharisa expansion project activities taking place. The following study approach was used:

- Maps, aerial photographs and digital satellite images were consulted along with the historical data provided, in order to identify all river sources and help understand the aquatic ecology of the area associated to the study areas.

- Historical biomonitoring reports were reviewed and considered to find trends within the aquatic ecosystems associated with the study areas.
- Reference to historical reports and existing data was made throughout this report.
- Important characteristics of the study area in terms of aquatic ecology were identified.
- Biomonitoring sites for future monitoring as part of the consolidated EMP were identified and mapped, to help with management and measures to mitigate the impacts on the aquatic ecology during the post closure and decommissioning phase of activities associated to the study areas.
- An impact assessment was undertaken in order to determine the risk to the aquatic ecosystem of the study area. Mitigation measures were included to help manage and lower any impact to the aquatic ecosystem.

3 SITE DESCRIPTION

Historical biomonitoring assessment sites are selected based on the position of the mining footprint to monitor any impacts of the current Tharisa mining activities. The sites selected represented upstream and downstream points along the Sterkstroom River and are presented in Figure 1. Historically annual assessments were conducted at the same sampling sites within the mining area and allowed temporal comparison.

Site A was selected as the upstream representative point and has been used in all historical reports (NSS 2008, 2010, 2011 and CS 2013). The downstream site B has been used by Natural Scientific Services for years 2008, 2010 and 2011 (NSS 2008, 2010, 2011). And due to limited access in 2013 the downstream site B1 was used by Clean Stream Biological Services CC (CS 2013).

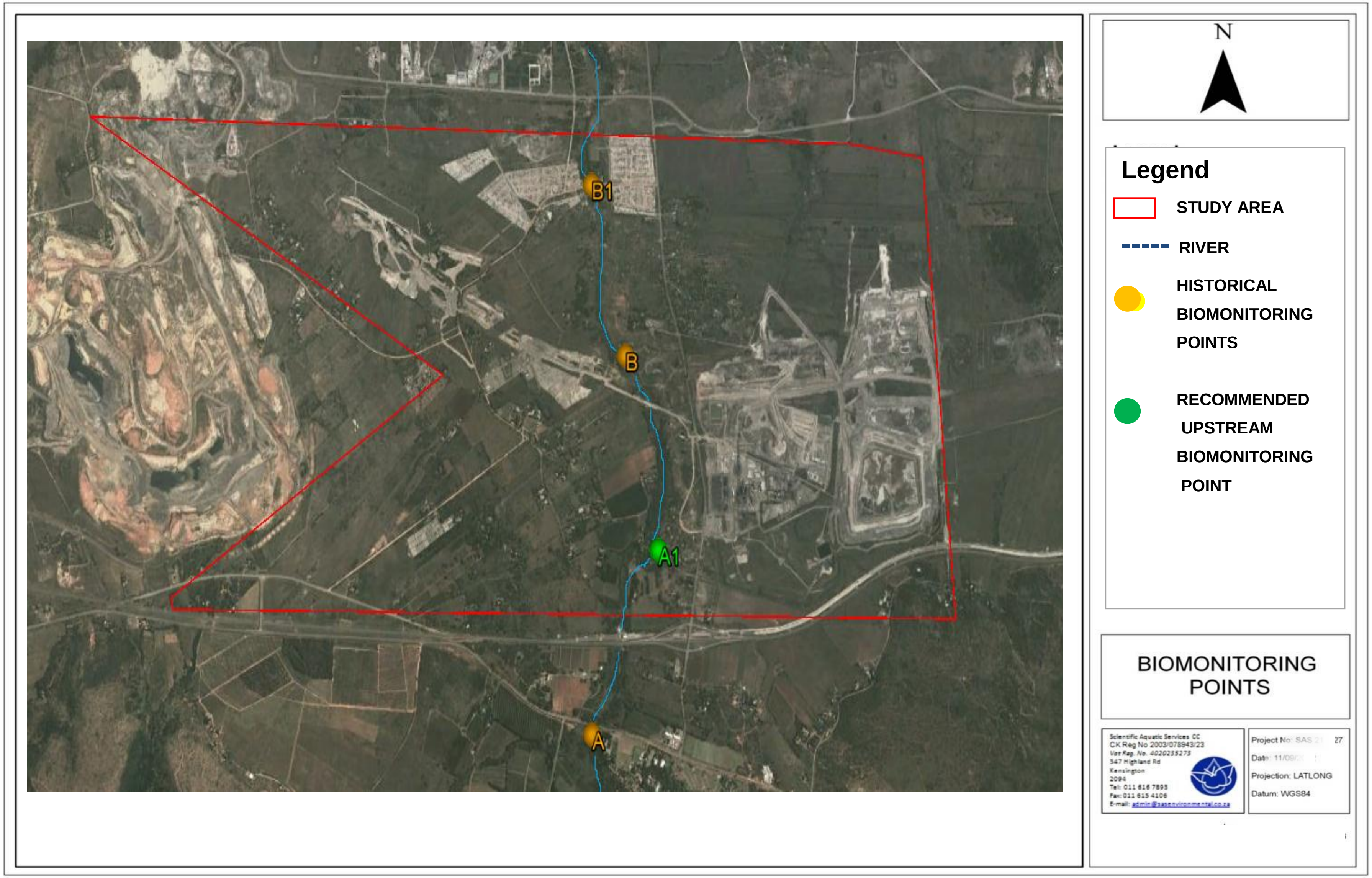


Figure 1: Historic biomonitoring assessment sites for the for the Tharisa mining subject property.

4 SYSTEM CHARACTERISATION AND ECOREGION

The subject property falls within the Bushveld Basin Ecoregions and is located within the A21K quaternary catchments (Kleynhans 1999) (Figure 2). According to the River Health Programme (RHP, 2005), the subject property falls within the Lower Sterkstroom of the Upper Crocodile Sub-Water Management Area (subWMA) where the overall Ecostatus, including macro-invertebrate integrity for this unit, is considered to be poor. The only perennial river flowing through the Tharisa mining footprint area is the Sterkstroom River. The major contributors to this poor status are mining operations, informal settlements and groundwater usage for citrus farming.

Table 2: Criteria and attributes assessed during the determination of the PES.

Catchment	Resource	EIS	PESC	DEMC
A21K	Sterkstroom River	Moderate	Class C	C: Moderately sensitive system

QUATERNARY CATCHMENT A21K

According to the ecological importance classification for the quaternary catchment, the system can be classified as a Moderately Sensitive System which, in its present state, can be considered a Class C (Moderately modified) stream.

The points below summarise the current impacts on the aquatic resources in the quaternary catchment A21K (Kleynhans 1999):

- The aquatic resources within this quaternary catchment have been moderately affected by bed modification.
- Flow modifications were assessed mainly downstream from Buffelspoort Dam and were found to have a marginal effect on the system.
- Impacts on the system as a result of the introduced aquatic biota with special mention of *Micropterus salmoides* (Largemouth bass) and *Cyprinus carpio* (Carp) are low.
- Impact due to inundation as a result of the Buffelsport Dam is considered moderate.
- Riparian zones and stream bank conditions are considered to be moderately impacted as a result of exotic vegetation and cultivated land.
- Impacts as a result of water quality modification are at a moderate level.

In terms of ecological functions, importance and sensitivity, the following points summarise the current conditions in this catchment:

- The riverine systems in this catchment have a high diversity of habitat types.
- The quaternary catchment has a moderate importance in terms of conservation and natural areas.
- The quaternary catchment has a high intolerance to flow and flow related water quality with special mention of A*mphilius uranoscopus* (Mountain catfish).
- The quaternary catchment is regarded as having no importance for rare and endangered species conservation.
- The quaternary catchment is considered of low importance in terms of provision of migration routes for faunal species in the instream and riparian environments.
- The quaternary catchment has a moderate importance in terms of providing refugia for aquatic community members.
- The quaternary catchment can be considered to have a moderate sensitivity to changes in water quality and flow.
- The quaternary catchment is of moderate importance in terms of species richness.
- The quaternary catchment is of high importance in terms of endemic and isolated species with special mention of A*mphilius uranoscopus* (Mountain catfish) and *Barbus motebensis* (Marico barb).

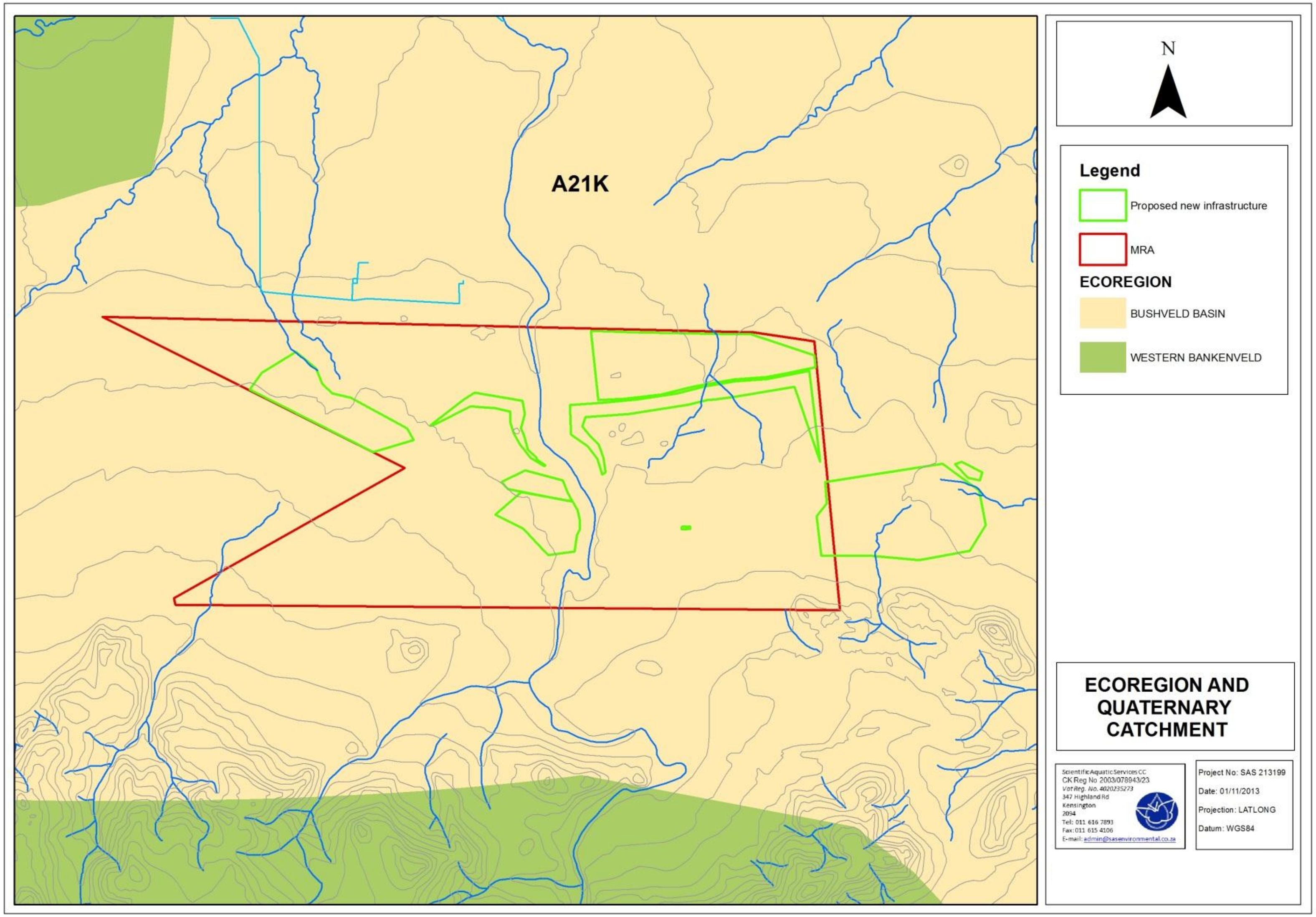


Figure 2: Map of the quaternary catchment and aquatic ecoregions of the area in relation to the Tharisa Mining Rights Area (MRA).

4.1 Aquatic assessment methodology

At both upstream (A) and downstream sites (B and B1) the water quality, habitat, riparian vegetation, macro-invertebrate and/or fish ecological integrity was evaluated using biological indices, including *in situ* water variables, nutrients and metal contamination assessments, Index of Habitat Integrity (IHI), Vegetation Response Assessment Index (VEGRAI), Macro-invertebrate Response Assessment Index (MIRAI), South African Scoring System (SASS5) and Fish Response Assessment Index (FRAI). For detailed methodology for each assessment refer to historical reports. Historical information summarised in the tables below originates from the reports previously indicated. Where historical data was not available, it is clearly indicated as such in the tables and in most cases been included by SAS using information form the reports.

5 STERKSTROOM RIVER HISTORICAL RESULTS (2008, 2010, 2011 AND 2013)

5.1 Visual assessment

- Visually the biomonitoring sites throughout the years have shown little variation with regards to in stream morphology, habitat suitability and faunal diversity for both historical upstream and downstream sites.
- Some general impact below the upstream site A along the N4 highway may be impacting on the Sterkstroom River (Figure 3). It is recommended that an additional biomonitoring site be included in the 2014 biomonitoring period until the N4 development has been completed, in order to distinguish between impacts on the Sterkstroom River emanating from the N4 and impacts emanating from Tharisa Mine. Refer to Figure 1 for the location of the proposed additional A1 biomonitoring site.
- The November site visit indicated that the downstream site B1 was dry (Figure 4). However, during August there was sufficient water to conduct biomonitoring (CS 2013).
- Additional visual records indicate that the Tharisa Mine does not abstract any water from the Sterkstroom River and is managing its water in a closed system between the west open pit and east open pit areas, which are respectively situated west and east of the Sterkstroom River (Figure 5).

Figure 3: 2013 Upstream Site A indicating good habitat and sufficient flow.

Figure 4: 2013 Downstream Site B1 was dry during the November site visit.

Figure 5: Pipe transferring water from west pit to Hernic Open pit over the Sterkstroom River

5.2 In-situ water quality

Available historical data presents key findings pertaining to biota specific water quality and potential impacts on the aquatic community for years 2008, 2010, 2011 and 2013. For purposes of temporal comparison with and interpretation of current results, selected data from these reports have been summarized for each respective reference point are presented in the table below. Results are spatially described for each year and then temporally compared for each site. The Target Water Quality Range (TWQR) Guidelines for South African waters are defined by the Department of Water Affairs and Forestry (DWAF, 1996) Vol 7.

Table 3: In-situ water quality variables measured during June 2008, July 2010, March 2011 and August 2013 assessments at the selected biomonitoring sites along the Sterkstroom River.

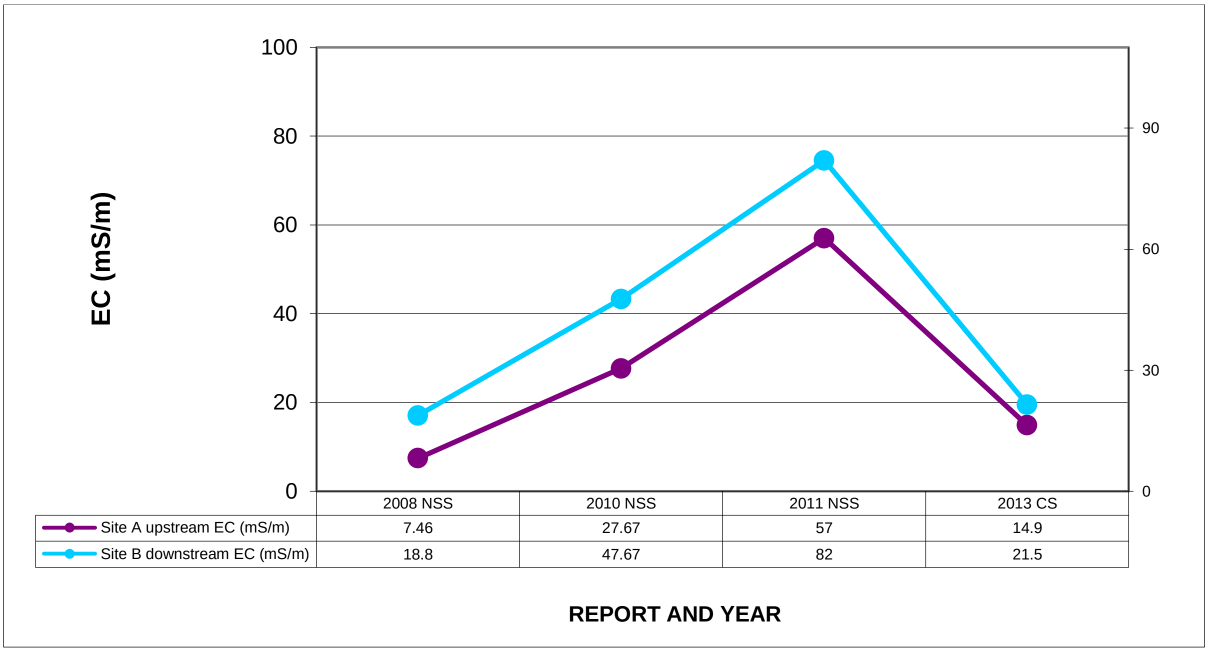
Reference	Site	EC (mS/m)	pH	DO %	DO (mg/l)	TDS (mg/l)	Temp (°C)
NSS 2008 LF	A	7.46	8.24	-	6.9	66	18.6
	B	18.8	8.34	-	6.5	106	18.5
NSS 2010 LF	A	27.67	7.8	90.53	8.75	28	10.7
	B	47.67	7.6	99.57	9.97	48	9.9
NSS 2011 HF	A	57	7.38	105.8	7.99	28	22.18
	B	82	7.18	109.5	7.99	41	23.97
CS 2013 LF	A	14.9	7.5	84.4	6.8	-	17.7
	B1	21.5	7.8	68.7	5.2	-	19.3

LF= Low flow and HF = High flow

5.3 Temporal in-situ water quality variables for EC, DO and pH measured for years 2008, 2010, 2011 and 2013

5.3.1 Upstream and downstream temporal EC values for years 2008, 2010, 2011 and 2013 (Figure 6)

- The reference Electrical Conductivity (EC) within the Tharisa Mine study area is 7.46 as measured from the upstream A site for the 2008 baseline study (NSS 2008)
- To meet TWQR guideline requirements the EC may not change by more than 15% for all EC scores for the Sterkstroom River system related to the Tharisa Mine area (DWAF 1996 Vol 7).
- Temporally for both upstream and downstream EC scores for 2008, 2010, 2011 and 2013, it is evident that there has been a marked increase of greater than 15%. Changes observed fall outside the TWQR guideline recommendations for all years in relation to the reference 2008 year.
- The EC value for 2011 was conducted during the high flow period where as 2008, 2010 and 2013 EC readings were taken during the low flow period.
- The temporal changes observed most likely resulted from the concentration of dissolved salts introduced from agricultural, anthropogenic as well as Tharisa mining activities taking place over the years, with a peak during the high flow period (2011) (Figure 6).

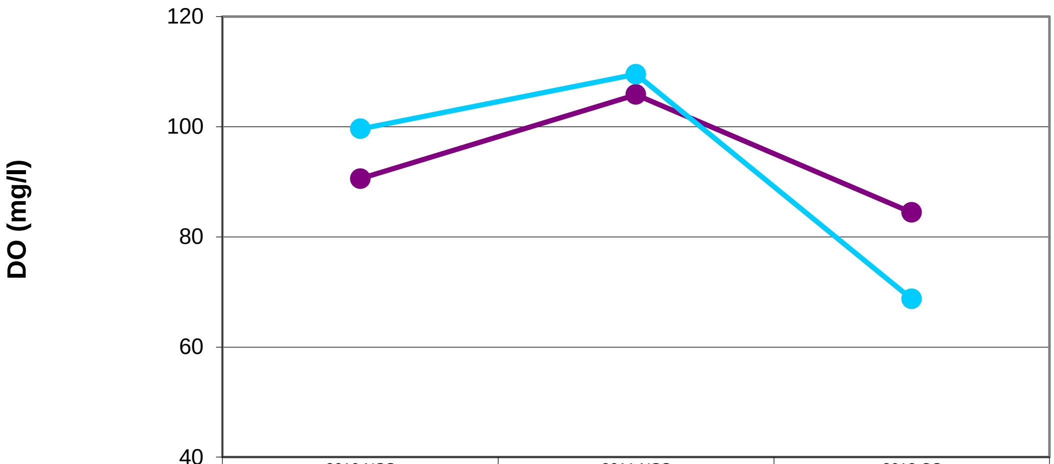


	2008 NSS	2010 NSS	2011 NSS	2013 CS
Site A upstream EC (mS/m)	7.46	27.67	57	14.9
Site B downstream EC (mS/m)	18.8	47.67	82	21.5

Figure 6: Upstream and downstream EC temporal variables measured for years 2008, 2010, 2011 and 2013.

5.3.2 Upstream and downstream temporal DO values for years 2010, 2011 and 2013 (Figure 7)

- TWQR guideline for Dissolved Oxygen (DO) should range between 80% and 120% saturation (DWAF 1996 Vol 7).
- The DO values measured during 2010 and 2011 for upstream and downstream sites were within the TWQR guideline for dissolved oxygen (DWAF 1996 Vol 7) and should not pose a risk to aquatic biota.
- The 2013 DO for the upstream site is within the TWQR guidelines with the only value outside of the TWQR guidelines being the new B1 downstream site for 2013.
- The reduction in the concentration of dissolved oxygen at site B1 could be caused by the reduction of the volume of water available for the saturation concentration of dissolved oxygen. In addition the downstream site during this survey comprise of a pool of water which may lower the DO concentration through the presence of oxygen-scavenging attributes and suspended particles.
- Actions due to Tharisa mining activities may also attribute to the reduction of the DO where the possible presence of oxidizable organic matter, either of natural origin (detritus) or originating in waste discharges, can lead to reduction in the concentration of dissolved oxygen in surface waters (DWAF 1996 Vol 7).
-



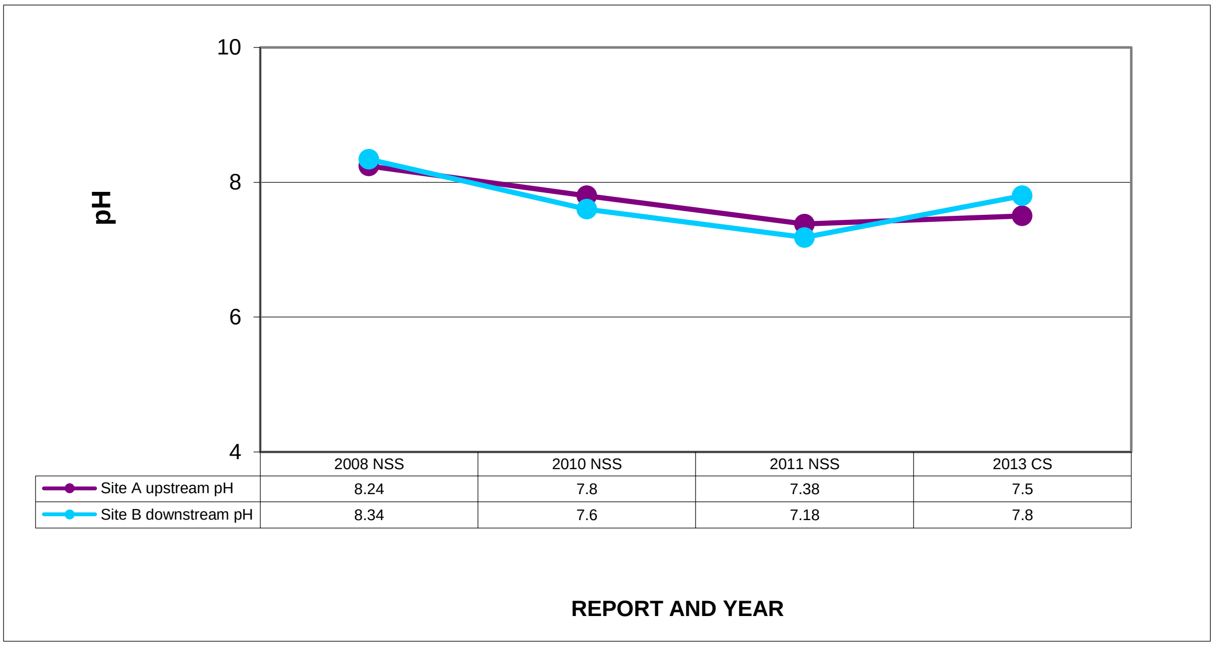
	2010 NSS	2011 NSS	2013 CS
Site A upstream DO (mg/l)	90.53	105.8	84.4
Site B downstream DO (mg/l)	99.57	109.5	68.7

REPORT AND YEAR

Figure 7: Upstream and downstream DO temporal variables measured for years 2010, 2011 and 2013.

5.3.3 Upstream and downstream temporal pH values for years 2008, 2010, 2011 and 2013 (Figure 8)

- According to the TWQR, most fresh waters in South Africa are relatively well buffered and more or less neutral, with pH ranges between 6 and 8. It is expected that most aquatic species will tolerate and reproduce successfully within this pH range (DWAF 1996 Vol 7).
- Elevated pH values can, however, be caused by increased biological activity in eutrophic systems. The pH values may fluctuate widely from below 6 to above 10 over a 24-hour period as a result of changing rates of photosynthesis and respiration (DWAF 1996 Vol 7).
- In the baseline year of 2008 the pH was high and showed signs of high alkalinity at both upstream and downstream sites, the pH range thus exceeded the TWQR (DWAF 1996 Vol 7) during that assessment. These high pH levels may have been a result of eutrophication taking place in the system during the time of sampling.



	2008 NSS	2010 NSS	2011 NSS	2013 CS
Site A upstream pH	8.24	7.8	7.38	7.5
Site B downstream pH	8.34	7.6	7.18	7.8

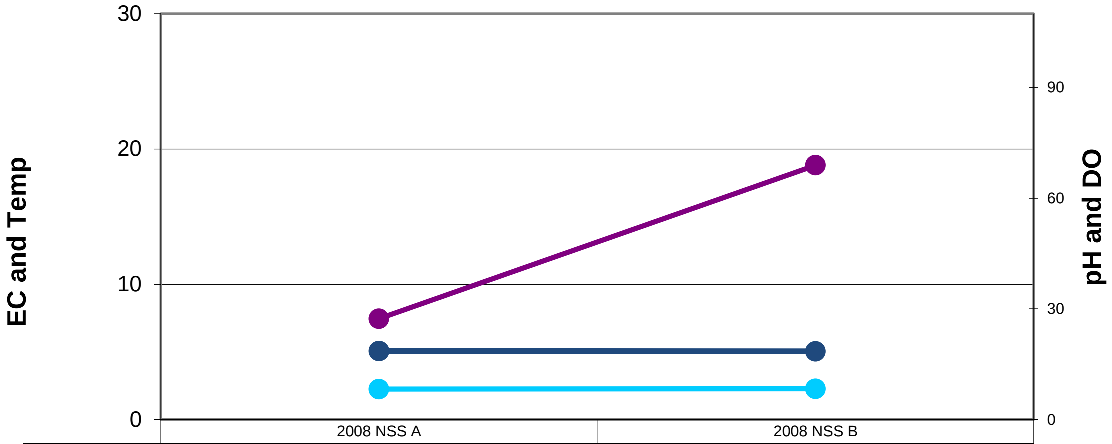
Figure 8: Upstream and downstream pH temporal variables measured for years 2008, 2010, 2011 and 2013.

5.4 Spatial in-situ water quality variables measured for years 2008, 2010, 2011 and 2013

5.4.1 June 2008 (LF) (Figure 9)

- The reference EC is taken from the upstream A site for the 2008 baseline study (NSS 2008) within the Tharisa Mine subject property. To meet TWQR guideline requirements EC in the system may not change by more than 15% compared to the reference condition (DWAF 1996 Vol 7).
- Spatially between the two sites (A and B) it is evident that there has been a marked increase of greater than 15%, which is outside the TWQR recommendation. EC has by a factor of 2.5x in a downstream direction. This observation is most likely resulting from the concentration of dissolved salts introduced from agricultural and anthropogenic activities to the system under the low flow conditions throughout the catchment during the 2008 sample period.
- From a spatial perspective the pH increased by 1% between the two sites. According to the TWQR the pH values should not be allowed to vary from the range of the background pH values for a specific site and time of day, by > 0.5 of a pH unit, or by > 5 %, and should be assessed by whichever estimate is the more conservative. The spatial change observed is thus well within TWQR guidelines.
- However, the pH was high and showed signs of high alkalinity at both sites, the pH range thus exceeded the TWQR (DWAF 1996 Vol 7) during the time of assessment. This high pH level may be a result of eutrophication taking place in the system during the time of sampling.
- The oxygen levels are below the acceptable levels, with the DO for both sites being below 8mg/l saturation, as per DWAF guidelines (1996). The low DO levels may be a result of the low flow volume of water and anthropogenic activities which will have an effect on the DO where water may be polluted. The amount of suspended material in the water affects the saturation concentration of dissolved oxygen, either chemically, through the oxygen-scavenging attributes of the suspended particles, or physically through reduction of the volume of water available for solution (DWAF 1996 Vol 7).
- No variation in temperature was observed between the sites and the temperature can be regarded as normal for the time of day and time of year when sampling took place.
- Overall for the 2008 documented results (NSS 2008) the EC, pH and DO values exceeded TWQR guidelines (DWAF 1996 Vol 7) and may impact on the receiving ecosystem at the time of study.

- The historical baseline documented results for 2008 (NSS 2008) *in-situ* water quality data results shows that the baseline conditions were already poor during the low flow 2008 biomonitoring period. Any additional negative impact on the system resulting in poorer (compared to baseline) water quality conditions, may obviously have severe negative repercussions for the receiving ecosystem. Continued assessments will indicate if such impacts could possibly result from Tharisa mining activities.



	2008 NSS A	2008 NSS B
EC mS/m	7.46	18.8
pH	8.24	8.34
DO mg/l		
Temp °C	18.6	18.5

SITE AND YEAR

Figure 9: Spatial In-situ water quality variables measured between the upstream and downstream sites for year 2008

5.4.2 July 2010 (LF) (Figure 10)

- Downstream of the Tharisa Mine it is evident that there has been a 71% increase in the EC. Spatially between the two sites (A and B) this increase exceeds TWQR guidelines (DWAF 1996 Vol 7).
- The observation is most likely resulting from agricultural and anthropogenic activities taking place between the two sites, as well as potential mining related activities which have taken place since 2008. Such activities may lead to amplified concentration of dissolved salts introduced to the system, especially under low flow conditions during the time of assessment.
- The pH decreased by less than 2% between the up and downstream sites. This change is within the 5% change from reference conditions (DWAF 1996 Vol 7).
- It is unlikely that the observed change in pH will lead to reduced aquatic ecological integrity.

- Dissolved oxygen concentration increased 9% in a downstream direction and this change is, however, within the target water quality objective for aquatic ecosystems (DWAF 1996 Vol 7).
- Limited variation in temperature was observed between the sites and the temperature can be regarded as normal for the time of day and time of year when sampling took place and the variation in stream volume at the two points.
- Overall for the 2010 documented results (NSS 2011) the *in-situ* pH, DO and temperature water quality variables remain constant and within the TWQR guideline (DWAF 1996 Vol 7) and should not pose a risk to aquatic biota. The EC values for the 2011 survey exceeds TWQR guidelines (DWAF 1996 Vol 7) and may have impacted on the receiving ecosystem.

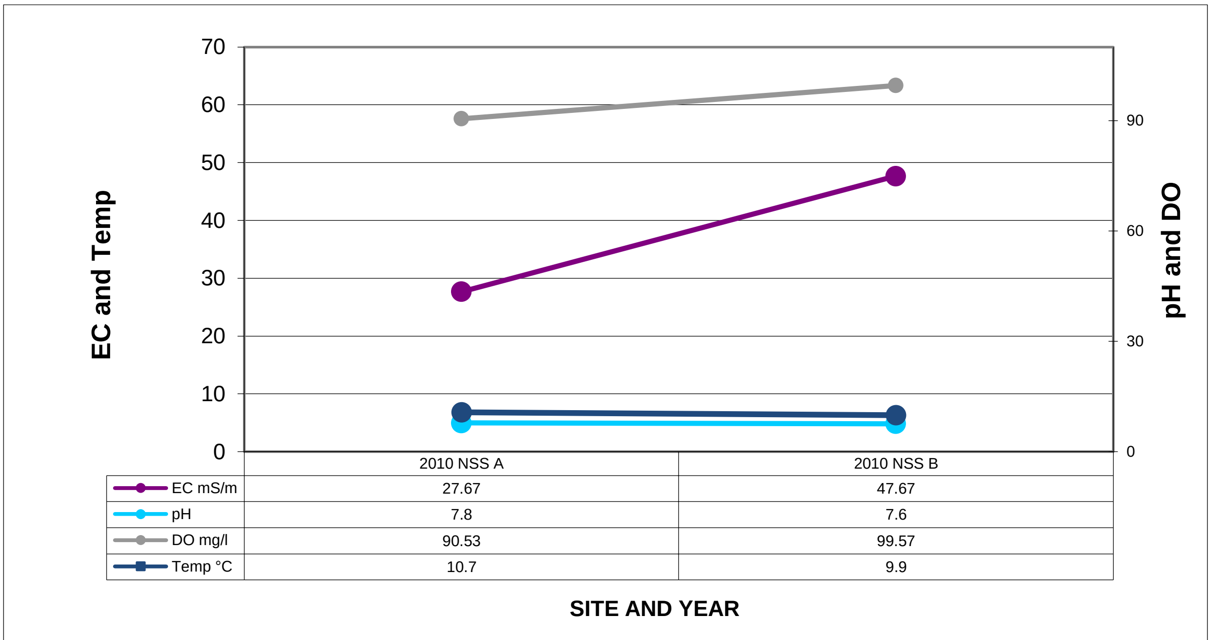


Figure 10: Spatial In-situ water quality variables measured between the upstream and downstream sites for year 2010

5.4.3 March 2011 (HF) (Figure 11)

- Spatially the EC increased in a downstream direction by 43%, indicating a potential source of pollution occurring between these sites at the time of sampling.
- The EC at both sites during the 2011 biomonitoring survey exceeds the reference EC taken from the upstream A site for the 2008 baseline study (NSS 2008) by more than 15% and thus does not meet TWQR guideline recommendations (DWAF 1996 Vol 7).
- Since 2008, the 2011 the EC has increased more than 3x the reference EC at the upstream site. This may be due to upstream impacts such as anthropogenic and agricultural activities taking place in the system.

- Since 2008 the EC has increased by more than 4x and indicates an increase concentration of dissolved salts entering the system between the upstream and downstream sites.
- This observation is most likely as a result from agricultural, anthropogenic and Tharisa Mine related activities taking place between the two sites which may lead to increased concentration of dissolved salts introduced to the system, especially under low flow conditions during the time of assessment.
- The pH decreased by less than 1% between the up and downstream sites and is between 6.5 and 9.0 pH units. It is expected that most aquatic species will tolerate and reproduce successfully within this pH range (DWAF 1996 Vol 7).
- The dissolved oxygen values measured at both sites were within the guideline for dissolved oxygen (DWAF 1996 Vol 7) and should not pose a risk to aquatic biota.
- Limited variation in temperature was observed between the sites and the temperature can be regarded as normal for the time of day and time of year when sampling took place and the variation in stream volume at the two points.
- In general from the 2011 documented results (NSS 2011) the *in-situ* pH, DO and temperature water quality variables remain constant and within the TWQR guideline (DWAF 1996 Vol 7) and should not pose a risk to aquatic biota. The EC values, however, for the 2011 survey exceeds TWQR guidelines (DWAF 1996 Vol 7) and may have impacted on the receiving ecosystem.

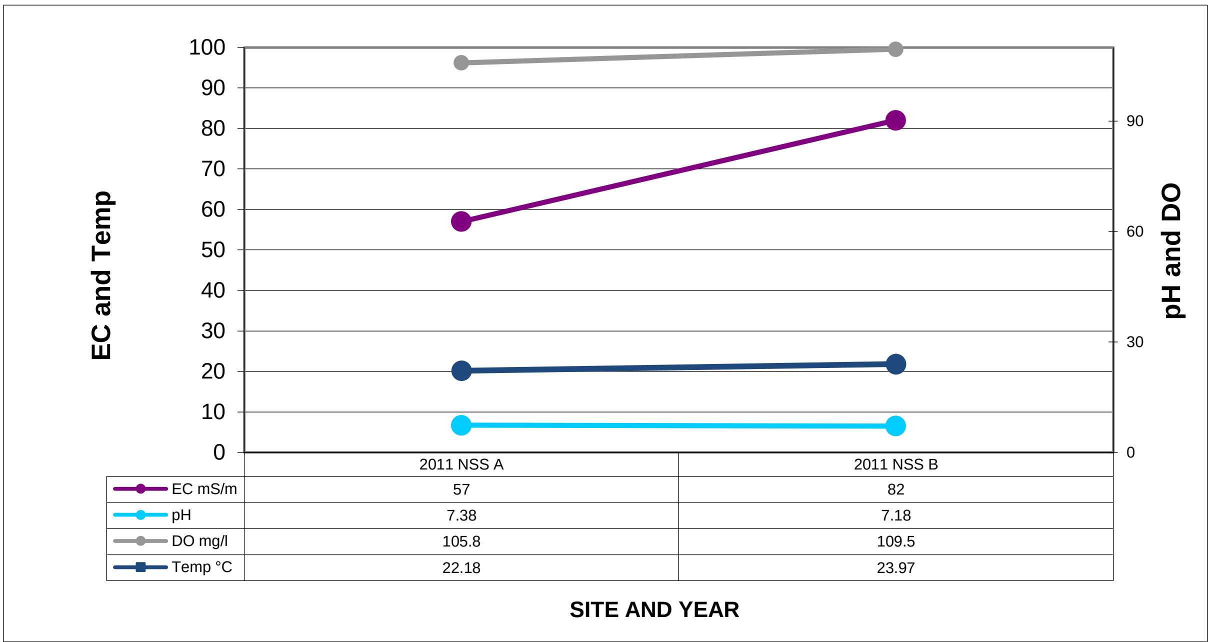


Figure 11: Spatial In-situ water quality variables measured between the upstream and downstream sites for year 2011

5.4.4 August 2013 (LF) (Figure 12)

- The EC during 2013 was low in comparison to 2010 and 2011 historical data. Spatially the EC increased between the upstream and downstream site by 44%. This increase indicates a slight potential source of salinisation occurring between these sites (at the time of sampling). These EC readings for 2013 compared to the baseline EC readings from 2008 saw a 99% increase between the two upstream sites as well as 3x at the downstream site and exceeds the TWQR guidelines (DWAF 1996 Vol 7).
- This observation is most likely as a result from agricultural, anthropogenic and Tharisa Mine related activities taking place between the two sites which may lead to an increased concentration of dissolved salts introduced to the system, especially under low flow conditions.
- The pH increased by less than 1% between the up and downstream sites. This change is within the 5% change from the guideline stipulated and these pH readings are well within the 6.5 and 9 pH guideline recommendations (DWAF 1996 Vol 7).
- The dissolved oxygen values measured decreased between the upstream site A and the new downstream site B1 by 22%.
- The DO saturation level at the upstream site was within the guideline for dissolved oxygen and should not pose a risk to aquatic biota (DWAF 1996 Vol 7).
- The DO saturation at the new downstream site was however below the accepted DWAF (1996) TWQR requirements. The lack of oxygen at this point may be due to the water body sampled comprising of a pool where low saturation could take place. The low oxygen levels may results in stress on the aquatic community at this time.
- Limited variation in temperature was observed between the sites and the temperature can be regarded as normal for the time of day and time of year when sampling took place and the variation in stream volume at the two points.
- Overall the results from the 2013 documented results (CS 2013) the EC values for the 2013 survey exceeds TWQR guidelines (DWAF 1996 Vol 7) and may impact on the receiving ecosystem. The other *in-situ* pH, DO and temperature water quality variables remain constant and within the TWQR guideline (DWAF 1996 Vol 7) and should not pose a risk to aquatic biota.

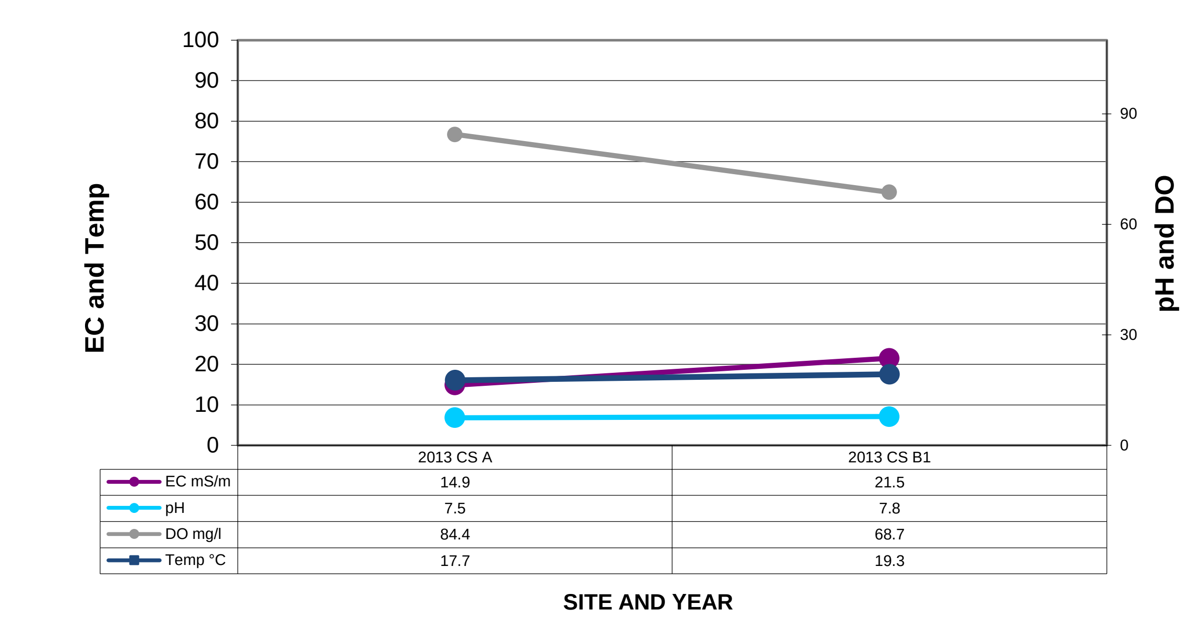


Figure 12: Spatial In-situ water quality variables measured between the upstream and downstream sites for year 2013.

5.5 Habitat integrity

Historical instream and riparian zone habitat integrity data of the Sterkstroom River observed at each of the sites for years 2010 and 2011, as determined using the Index of Habitat Integrity (IHI) Kleynhans (1996), are presented below. SAS included the IHI from the date available in the August 2013 report provided by Clean Stream Biological Services CC (CS 2013).

Table 4: IHI results along the selected biomonitoring sites within the Sterkstroom River for years 2010, 2011 and 2013.

Reference	Site	Method	Instream score	Riparian zone score	Total habitat score	IHI classification
NSS 2010	A	IHI	60	42	51	Largely modified
	B	IHI	62	60	61	Moderately modified
NSS 2011	A	IHI	62	58	50	Largely modified
	B	IHI	44	54	48	Largely modified
SAS-CS 2013	A	IHI	* 58	* 51	* 54	* Largely modified
	B1	IHI	* 50	* 47	* 49	* Largely modified

* Calculations done by SAS from reference report data information

- For the 2010, 2011 and 2012 years the IHI site scores and classifications were generally similar with the instream and riparian habitats being classified as being largely modified, with exception for the downstream site during 2010 indicating a moderately modified habitat score.
- The most likely causes of these modifications were flow modifications and water abstraction that resulted from the presence of the Buffelspoort Dam situated upstream from the sites (NSS 2010 and 2011).

5.6 Aquatic invertebrate assessment: SASS5 and MIRAI for (2010 and 2011)

Historical South African Scoring System 5 (SASS5) scores, Average Score per Taxon (ASPT) values and PES classes for sites along the Sterkstroom River for years 2008, 2010, 2011 and 2013 are summarized in the table below. The Macroinvertebrate Response Assessment Index (MIRAI) scores for 2010 and 2011 are also presented.

5.6.1 High flow SASS results for years 2008 and 2011

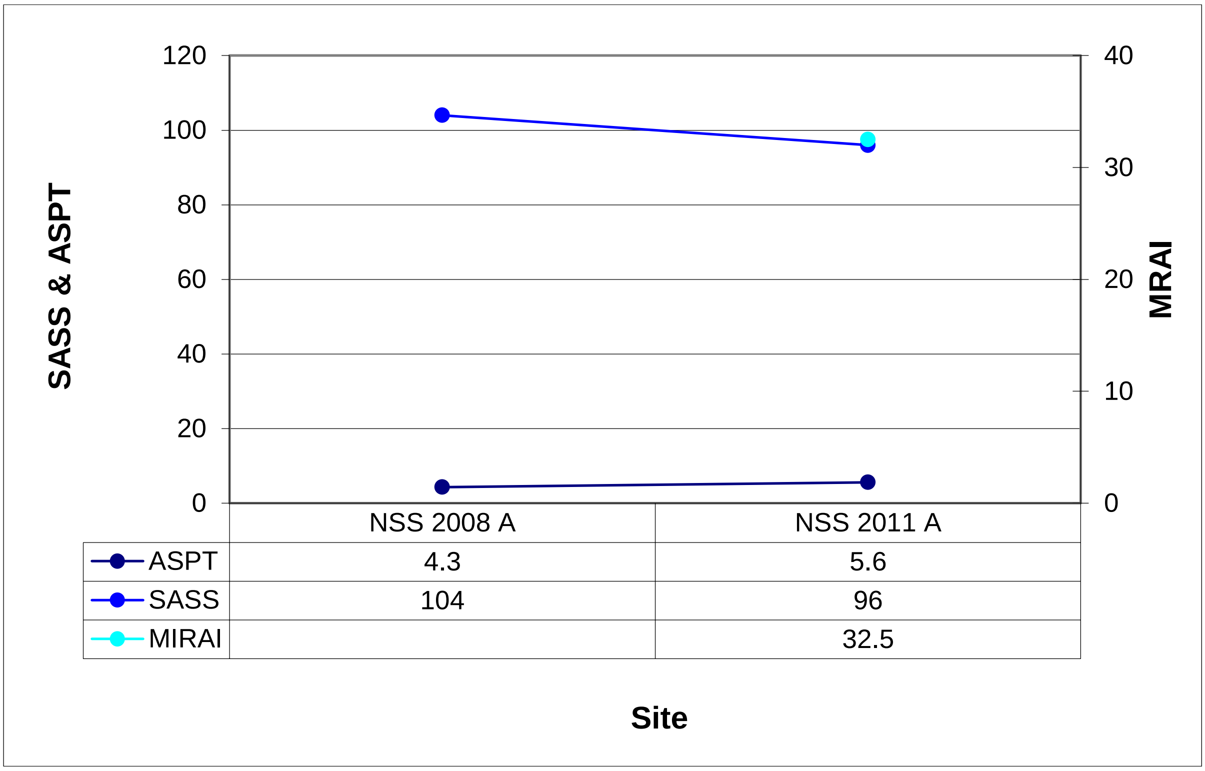
Table 5: High flow macro invertebrate assemblage results along the selected biomonitoring sites within the Sterkstroom River for years 2008 and 2011, including MIRAI for the 2011 survey.

Reference	Site	Method	SIC	VEG	GSM	ASPT	SCORE	Classification
NSS 2008	A	SASS	40	47	27	4.3	104	C
	B	SASS	57	17	27	4.1	66	E
NSS 2011	A	SASS				5.6	96	D
	B	SASS				4.8	77	E
NSS 2011	A	MIRAI					32.5	E
	B	MIRAI					34.4	E

No high flow (HF) data was available for the 2013 results (CS 2013)

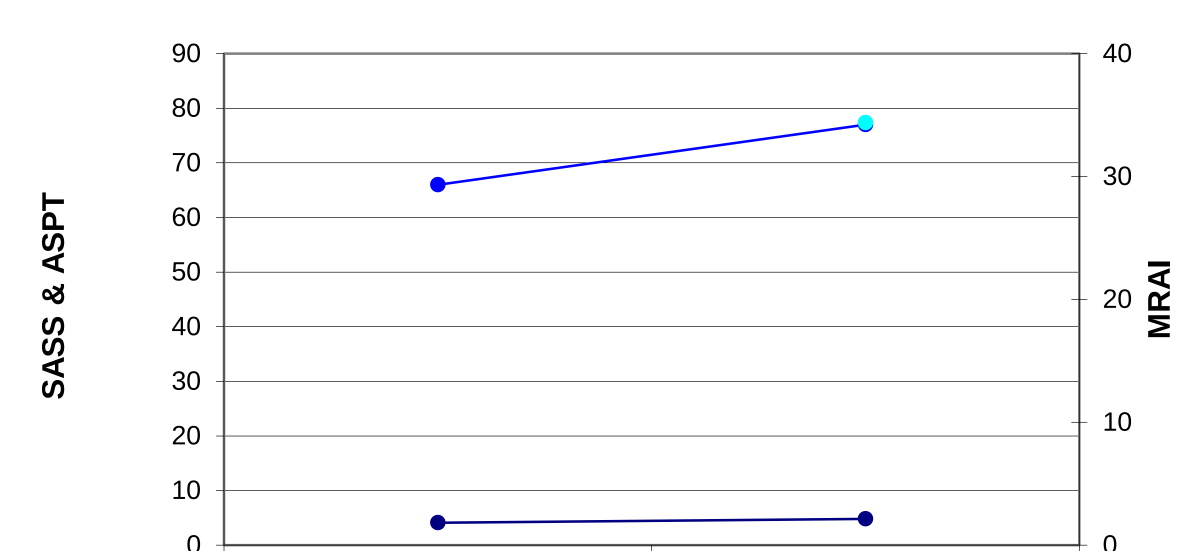
- Temporally at the upstream site A between 2008 and 2011, the SASS results were a class lower than the baseline results obtained in 2008. This shows that between 2008 and 2011 activities upstream of the Tharisa mining study area may have been impacting on the macro-invertebrate community (refer to Figure 13).
- The SASS data indicates that the aquatic macro-invertebrate community in this section of the Sterkstroom River has suffered a general loss in integrity throughout the area, when compared to the reference score for a pristine ecoregion system.

- Temporally between 2008 and 2011, downstream site B SASS scores indicated that the classes remained at a class E. No impact on the macro-invertebrate community is deemed to be taking place form any Tharisa mining related activities, as evaluated between 2008 and 2011 (high flow biomonitoring periods) (Figure 14).
- Anthropogenic and mining related activities, along with possible altered water quality, may be the primary drivers in the MIRAI score and may impact on the aquatic community in the Sterkstroom River system.
- Any impacts from mining activities on the aquatic community are most likely limited in effect. It is most likely that the activities associated with the local informal housing development at the lower site have an equally significant impact on the aquatic community of the Sterkstroom River in the vicinity of the Tharisa Mine.
- Only low flow 2013 and no high flow data were available for the 2013 results (CS 2013).



	NSS 2008 A	NSS 2011 A
ASPT	4.3	5.6
SASS	104	96
MIRAI		32.5

Figure 13: Longer term change in the system along the Sterkstroom River for the upstream sites between 2008 and 2011 during the high flow periods.



	NSS 2008 B	NSS 2011 B
ASPT	4.1	4.8
SASS	66	77
MIRAI		34.4

Figure 14: Longer term change in the system along the Sterkstroom River for the downstream sites between 2008 and 2011 during the high flow periods.

5.6.2 Low flow SASS results for years 2008, 2010 and 2013

Table 6: Low flow macro invertebrate assemblage results along the selected biomonitoring sites within the Sterkstroom River for years 2008, 2010, 2011 and 2013, including MIRAI for the 2010 survey.

Reference	Site	Method	SIC	VEG	GSM	ASPT	SCORE	Classification
NSS 2008	A	SASS	40	37	30	4.2	76	D
	B	SASS	57	3	27	4.2	71	E
NSS 2010	A	SASS	Na	Na	Na	5.68	108	* C
	B	SASS	Na	Na	Na	5	75	* D
NSS 2010	A	MIRAI	Na	Na	Na	Na	59.2	D
	B	MIRAI	Na	Na	Na	Na	53.2	D
CS 2013	A	SASS	36	49	17	4.06	65	* E
	B1	SASS	19	24	15	4.00	30	* E/F
SAS-CS 2013	A	MIRAI	Na	Na	Na	Na	* 40.5	* E
	B1	MIRAI	Na	Na	Na	Na	* 27.8	* E

* Calculations done by SAS from reference report data information
Na = Not available

- For the low flow biomonitoring periods the SASS data indicates that the aquatic macro-invertebrate community in this section of the Sterkstroom River has suffered a general loss in integrity throughout the area when compared to the reference score for a pristine ecoregion system.
- Temporally there was a 70% increase in SASS score at the upstream site A obtained between 2008 and 2010 (Figures 15 and 16). This shows that the activities upstream of the study area have had no negative impact on the macro-invertebrate community over these years.
- At the downstream site between 2008 and 2010 there is a SASS score increase of 5%. This thus indicates that there has been no impact occurring between the two downstream sites for 2008 and 2010.
- The 2013 upstream SASS result is 17% lower than the 2008 baseline SASS score. This fluctuation can be attributed to the change in flow between the high flow and low flow periods.
- The downstream 2013 SASS score has decreased by 2x since 2008. One possible contributing factor was the change between the downstream site B to site B1 (refer to

Figure 1). It is also possible that mining activities by Tharisa Mine over the years may be impacting on the water quality and the Sterkstroom River.

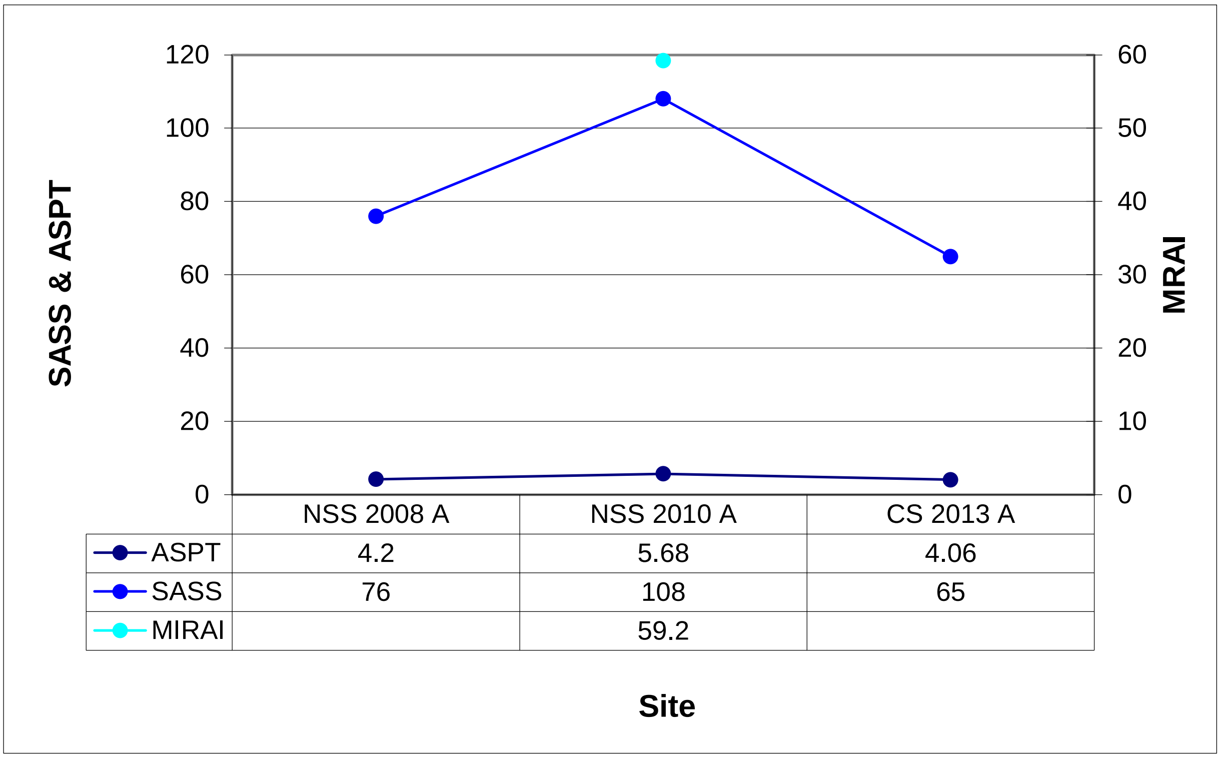


Figure 15: Longer term change in the system along the Sterkstroom River for the upstream sites between 2008, 2010 and 2013 during the low flow period.

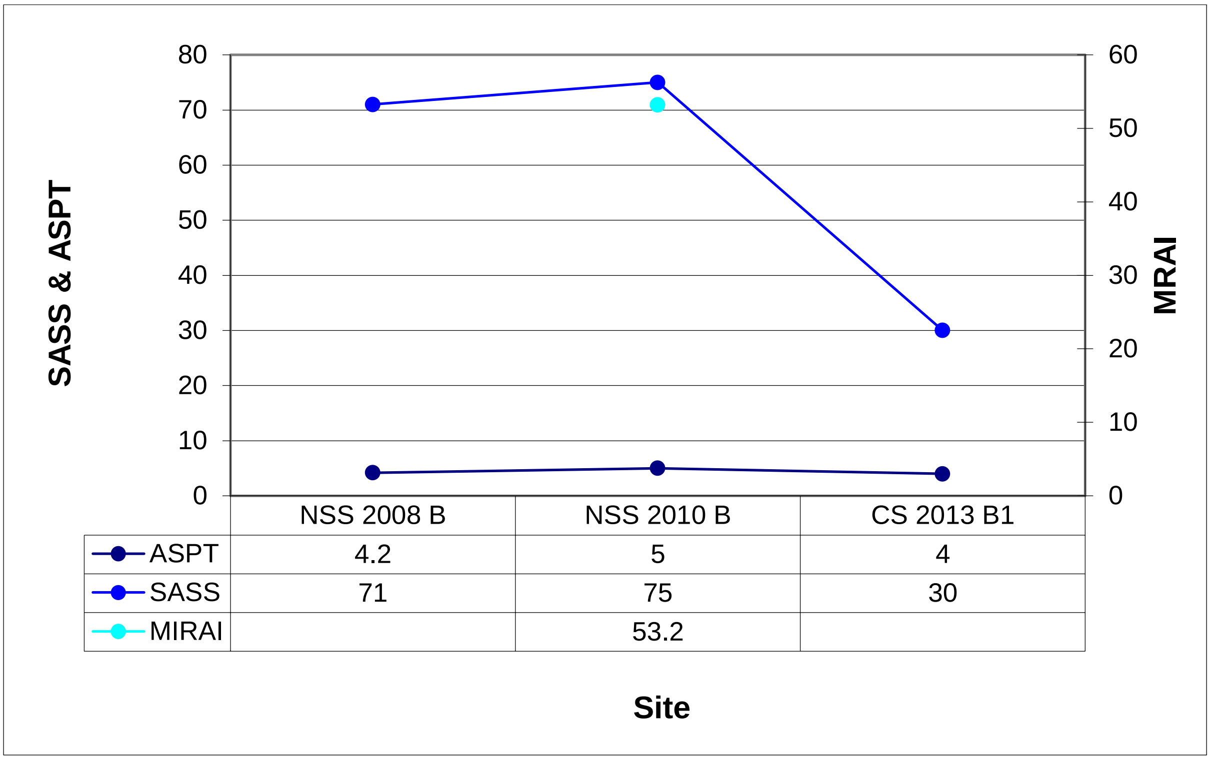


Figure 16: Longer term change in the system along the Sterkstroom River for the downstream sites between 2008. 2010 and 2013 during the low flow period

5.6.3 MIRAI results for years 2010, 2011 and 2013

- The MIRAI data for years 2011 and 2013 indicates that the aquatic macro-invertebrate community in this section of the Sterkstroom River has suffered a general loss in integrity throughout the area when compared to the reference score of 2010 across high and low flow periods (Figure 17).
- The baseline MIRAI reference classification for both upstream and downstream sites for 2010 indicated moderately modified class D. For both upstream and downstream sites the classification deteriorated to class E (critically modified) during the 2011 and 2013 assessments.
- The changes in MIRAI may be due to mine related activities, however, another contributing factor may be flow alteration within the Sterktroom system.
- The new downstream site B1 also indicated a MIRAI classification of critically modified class E with a low score of 27.8 (refer to light blue bar in Figure 17).

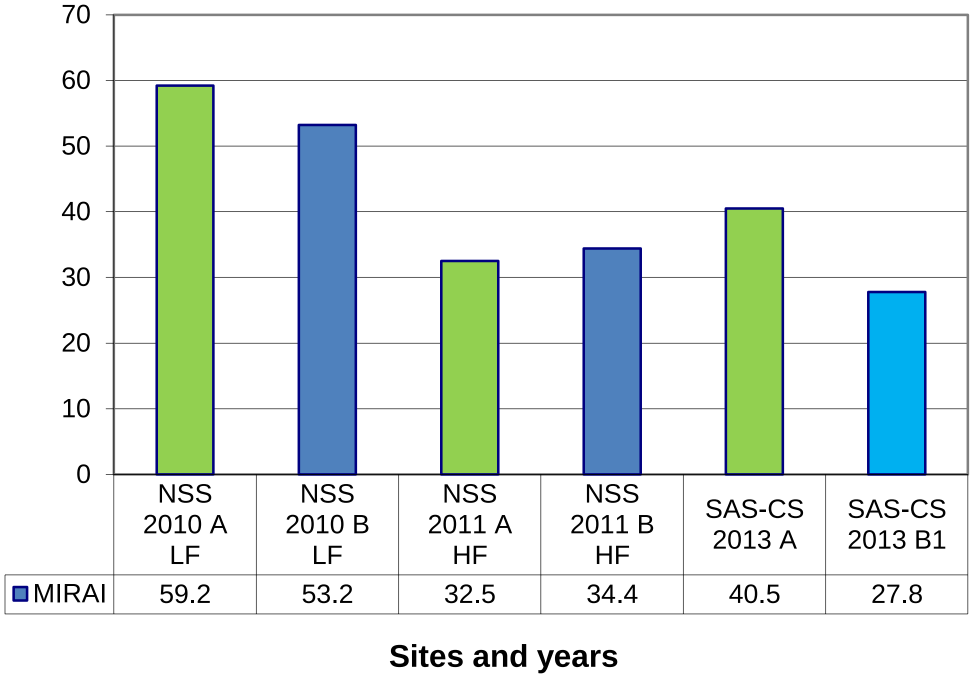


Figure 17: MIRAI data along the Sterkstroom River for the sites between 2010, 2011 and including the CS 2013 SASS data which has been updated to MIRAI for 2013 by SAS.

5.7 Fish Assemblage Results

Fish assemblage assessments only started in 2010. Fish habitat availability is an important component to consider when evaluating the fish availability within aquatic monitoring, especially when making temporal comparisons. The available historical data presents fish assemblage data for years 2010, 2011 and 2013. NSS utilised Fish Response Assessment Index (FRAI) methodology during the years of 2010 and 2011 and CS used Fish Assemblage Integrity Index (FAII) methodology during 2013. The results are represented in the table below and discussed. In addition from the CS 2013 FAII, SAS has calculated the FRAI based on the 2013 data and it is indicated below in Table 7.

Table 7: Fish assemblage results at the selected biomonitoring sites along the Sterkstroom River for years 2010, 2011 and 2013.

Reference	Site	Method used	Fish assemblage	Score	Class
NSS 2010	A	FRAI	*Barbus trimaculatus* *Tilapia sparrmanii* *Labeobarbus marequensis* *Chetia flaviventris*	65.6	C
	B	FRAI	*Barbus trimaculatus* *Tilapia sparrmanii* *Pseudocrenilabrus philander*	57.7	C/D
NSS 2011	A	FRAI	*Clarias gariepinus* *Barbus trimaculatus* *Labeobarbus marequensis* *Chetia flaviventris*	65.6	C
	B	FRAI	*Clarias gariepinus* *Tilapia sparrmanii* *Pseudocrenilabrus philander* *Labeobarbus marequensis* *Barbus paludinosis*	62.6	C
CS 2013	A	FAII	*Barbus trimaculatus* *Labeobarbus marequensis*	19	* F
	B1	FAII	*Barbus paludinosis* *Pseudocrenilabrus philander* *Tilapia sparrmanii*	20	* F
SAS-CS 2013	A	FRAI	*Barbus trimaculatus* *Labeobarbus marequensis*	* 62.2	* C
	B1	FRAI	*Barbus paludinosis* *Pseudocrenilabrus philander* *Tilapia sparrmanii*	* 61.7	* C

* Calculations done by SAS from reference report data information

For 2010 and 2011 using FRAI (NSS 2010 and 2011) and calculation of FRAI from the CS 2013 FAII data

- According to these scores, the fish assemblages were moderately modified at both sites for 2010 and 2011 survey periods. These results were primarily due to the lower number of indigenous species present in comparison to the expected fish species, which were based on fish studies conducted in the Sterkstroom catchment.
- Upon spatial comparisons between the two sites, the downstream site B (dark blue in Figure 18) fish assemblage score remains slightly lower than the upstream site A score (green bars in Figure 17), with classes ranging between moderately modified (C) and largely modified (C/D).
- This indicates that activities relating to Tharisa Mine have not impacted on the fish assemblage along the Sterkstroom River (Figure 18).
- The FRAI scores for 2013 were calculated from the FAII scores which were provided in the August 2013 Clean Stream Biological Services CC report.
- The 2013 FAII scores were almost identical, on a spatial scale, which is an indication that the biotic integrity, based on fish community composition, was not negatively affected by Tharisa Mine impacts at the time of sampling. An FAII classification of F was achieved, which is considered critically modified with an extremely lowered species richness and an absence of intolerant and moderately intolerant species. Only tolerant species may be present with a complete loss of species at the lower limit of the class. Impairment of health is also generally very evident (Kleynhans 1999).

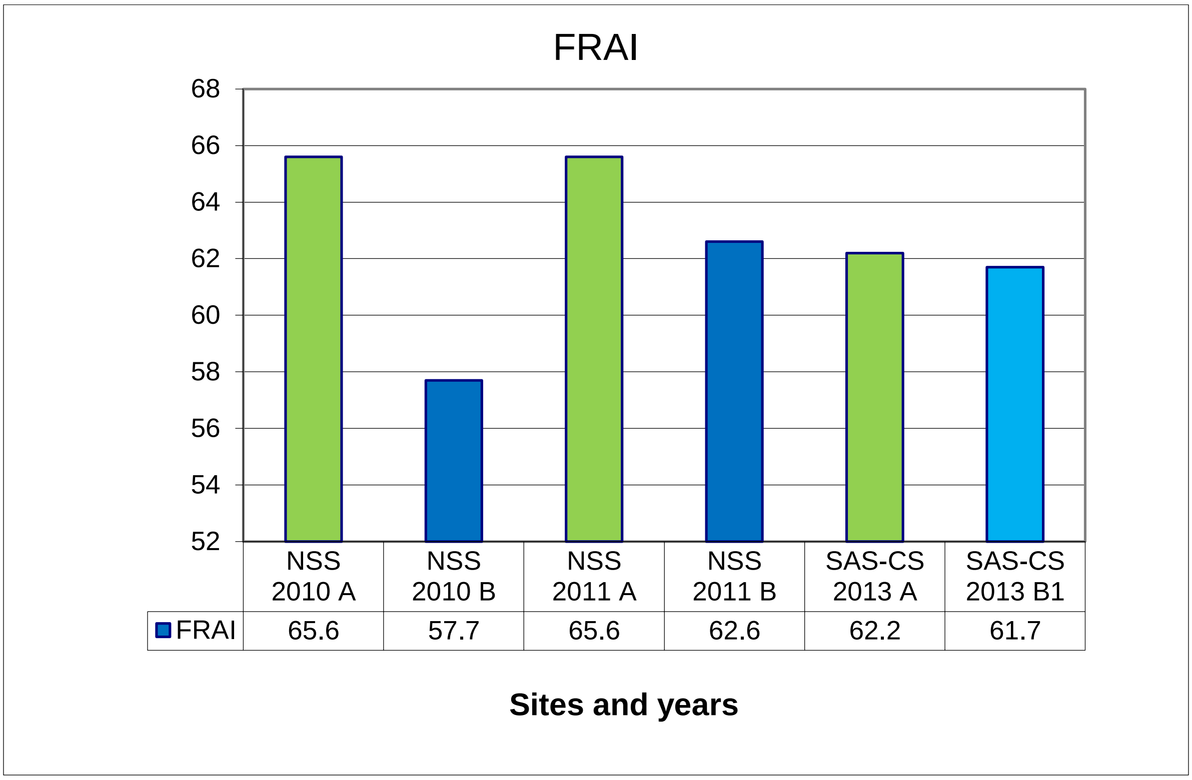


Figure 18: Fish assemblages FRAI scores along the Sterkstroom River for years 2010, 2011 and including FRAI calculation for 2013 from FAII data.

6 IMPACT ASSESSMENT

The impact assessment exercise was undertaken on all aspects of aquatic ecology deemed likely to be affected by the Tharisa Mine activities. The sections below present the results of the findings per identified risk/impact for the instream and riparian zones of the study area.

Historical impacts which are known to take place in the Sterkstroom River which were highlighted in NSS 2011 are;

- Flow modifications from upstream Bufflespoort Dam resulting in unnaturally high flow conditions.
- Erosion due to rural activities within the riparian zone.
- Additional human impacts on surface water quality and the disturbance of biotopes include intensive washing activities (bathing and laundry) and the use of agricultural chemicals and fertilizers. The use of detergents, runoff of pesticides, herbicides and fertilizers has an impact on the water quality.
- Litter was evident at both sites, particularly at downstream site B1. The disposal of litter and solid waste into the rivers is aesthetically displeasing and can cause blockages of water flow. If eaten by birds and other animals it is also dangerous
- There is large population of domestic livestock that utilize the river. This will increase faecal pollution and other livestock associated impacts.
- There are many existing river crossings by roads. Some are in poor condition due to either poor construction or inadequate maintenance. These crossings can change the flow regime downstream. Erosion and sediment runoff can also result in increased sediment load in the river. Changes in flow and water quality can impact on the type and abundance of taxa in the river and the biotopes they utilise.

The tables in the subsections below serve to summarise the activities which may lead to impacts on the aquatic ecology of the Sterkstroom River system within the study area and indicate the impact significance on aquatic resources. The significance of each impact was assessed separately for the pre-construction, construction operational and decommissioning and closure phases of the proposed project.

6.1 IMPACT 1: Loss of Instream Flow, Aquatic Refugia and Flow Dependent Taxa

The Sterkstroom River system within the study area does not undergo any abstraction of water for mining purposes. Abstraction activities do, however, occur for the production of crops such along the Sterkstroom River. These water uses lead to the lower sections of the Sterkstroom River being dry for some time of the year and few refuge pools for aquatic biota occur in these lower areas, such as at site B1 which was observed during the November survey. Any impact on instream flow will therefore be significant and can have a significant impact on the Sterkstroom River Ecology.

In terms of aquatic and riparian zone ecology in the vicinity of the study area, the Sterkstroom River is the most significant and requires the most attention when considering impacts on reduced instream flow and aquatic refugia and the loss of flow dependant taxa.

Dewatering may be occurring in the Sterkstroom River due to the Hernic open pit (quarry) where the mines closed water system is stored. The 2013 November site visit indicated that no water was identified at the downstream site B1 in comparison to the upstream site A (refer to Figure 3 and 4). The Hernic Quarry currently has a water level which is lower than the level of the adjacent Sterkstroom River. The quarry therefore has the potential to lead to dewatering of the Sterkstroom which could have an impact on the instream and riparian habitat on the areas on the Sterkstroom downstream of this point. In turn impacts on instream flow and habitat has the potential to impact on aquatic and riparian communities. The interactions between the Hernic Quarry and the Sterkstroom River need to be clearly defined by a suitably qualified geohydrologist.

If the Tharisa Mining operations expand and the mine disposes of more dirty water in the Hernic Quarry this will raise the water level within the quarry. Should this level increase to above the level of the Sterkstroom River a hydraulic head may form which could lead to movement of contaminated water to the Sterkstroom River which could lead to impacts on the local and downstream instream ecology leading to a loss of aquatic biodiversity and general aquatic community sensitivity.

Activities potentially leading to impact

Pre-Construction	Construction	Operational	Decommissioning & Closure
Poor planning leading extensive dirty water areas which need to be managed and reducing the MAR to the drainage systems in the area	Clearing of areas for the initiation of the production pits	Loss of MAR from dirty water areas	Loss of MAR from latent dirty water areas
The open pits being too near to drainage features may lead to loss of stream flow and base flow due to the formation of a cone of dewatering by the open pits	Construction of clean and dirty water separation structures for pollution control purposes.	Loss of water through clean and dirty water separation	Loss of water to inadequately rehabilitated areas such as discard dumps and open pits
Use of surface runoff and groundwater sources for the supply of production water for the mining project	Use of surface water runoff and groundwater as a water supply during construction	The formation of a cone of dewatering created by the Hernic open pit and other open pits	Use of surface water runoff and groundwater as a water supply during the closure phase of the mine
		Use of surface water runoff and groundwater as a water supply during the operational phase of the mine	Impact on natural streamflow regulation and stream recharge due to altered hydrology in the area
		Impact on natural streamflow regulation and stream recharge due to altered hydrology in the area	The formation of a cone of dewatering created by the Hernic open pit and other quarries

Aspects of aquatic ecology affected

Construction	Operational	Decommissioning & Closure
Loss of instream surface and base flow	Loss of instream surface and base flow	Loss of instream surface and base flow
The drying out of aquatic refugia in the Sterkstroom River	The drying out of aquatic refugia in the Sterkstroom River	The drying out of aquatic refugia in the Sterkstroom River
Loss of streamflow regulation and stream recharge	Loss of streamflow regulation and stream recharge	Loss of streamflow regulation and stream recharge
Loss of aquatic habitats for aquatic macro-invertebrates and fish	Loss of aquatic habitats for aquatic macro-invertebrates and fish	Loss of aquatic habitats for aquatic macro-invertebrates and fish
Increased moisture stress on riparian vegetation	Increased moisture stress on riparian vegetation	Increased moisture stress on riparian vegetation

Without Management	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
Sterkstroom River	4	3	3	4	5	7	11	77 (Medium-high)

Essential mitigation measures:

- Ensure that as far as possible all infrastructure is placed outside of wetland areas and streams. In particular mention is made of the need to not encroach on the riparian systems of the mine and a minimum buffer of 100m around all wetland and riparian systems should be maintained in line with the requirements of regulation GN704 of the National Water Act.
- Limit the footprint area of future construction activity to what is absolutely essential in order to minimise the loss of clean water runoff areas and the concomitant recharge of streams in the area.
- No use of clean surface water or any groundwater which potentially recharges the watercourses in the area should take place. In this regard specific mention is made of any water use which will affect the instream flow in the Sterkstroom River.
- Very strict control of water consumption must take place and detailed monitoring must take place. All water usage must continuously be optomised.
- Pollution control dams should be off stream structures and not within the natural drainage system of the area, thereby minimising impacts loss of instream flow and downstream recharge.
- Permit only essential construction personnel within 100m of all riparian systems.
- Keep all demarcated sensitive zones outside of the construction area off limits during the construction phase of the development.
- Implement alien vegetation control program within wetland areas with special mention of water loving tree species.
- Monitor all affected riparian systems for moisture stress.
- Monitor all potentially affected riparian zones for changes in riparian vegetation structure.
- Ongoing aquatic ecological monitoring must take place on a 6 monthly basis by an SA RHP Accredited assessor.

Recommended mitigation measures:

- The extent of the operations within the eastern and western mining areas of the Sterkstroom River must be kept to an absolute minimum.
- No infrastructure or open pits should encroach into any major drainage lines.

With Management	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
Sterkstroom River	3	3	2	3	4	6	9	54 (Medium-low)

Probable latent impacts

- Dewatering may be occurring in the Sterkstroom River due to the Tharisa mining activities, in-depth investigation by a qualified geohydrologist is recommended.
- The effect of the water table relationship of the Sterkstroom River and the Hernic open pit should be investigated by a geohydrologist to verify what the possible movement potential will be and what impact there could be if the water table in the Hernic pit is higher than the underground water table of the Sterkstroom River.
- Reduced recharge of the Sterkstroom River and other riparian systems affected by upstream and adjacent mining.
- Reduced availability of refugia for aquatic biota.
- Altered riparian vegetation structures.

6.2 IMPACT 2: Impacts on Water Quality Affecting Aquatic Ecology

The philosophy supporting the following section is that if all constituents in the cumulative discharge from within the study area are within the applicable target water quality ranges, then the activities taking place during operational phase by Tharisa Mine will not contribute significantly to an unacceptable cumulative impact.

Thus the precautionary principle requires that a conservative approach be taken, in this case to account for possible discharge of pollutants by future activities in the river catchment and especially in the Sterkstroom River.

6.2.1 Potential for increased erosion to occur

In the natural state of the project site, vegetation cover causes friction to rainfall run-off, that reduces flow velocities and consequently shear forces between the water and the ground surface, resulting in the ground surface remaining intact and not being eroded away. If for any reason flow velocities are increased, there is potential for increased erosion to occur.

Increased erosion of disturbed surfaces means that the run-off contains a higher silt or sediment load, which is discharged to the Sterkstroom River. A component of this sediment load is particles fine enough to remain in suspension, ‘clouding’ or ‘muddying’ the water.

The extent of this effect can be quantified by measuring a water quality parameter, suspended solids. If there are too many suspended solids in the water this can negatively affect biological life. In addition, a changed sediment load could have similar morphological effects to the river as changing peak flow rates, such as changes in channel character or dimensions and changes to bed roughness. Severe sediment deposition in the Sterkstroom River could lead to reduced surface flows in the system with a larger volume of water moving through a thickened layer. All of these changes could potentially affect biological life.

The following activities are likely to cause an increase in flow velocities, or directly increase erosion:

- Stripping (vegetation clearance) of mining areas prior to excavation of pits;
- Construction of hard-standing areas that increase run-off volumes, including roads, buildings and paved areas;
- Canalisation of run-off, particularly if canals do not discharge directly into the Sterkstroom River; and
- Construction activities that loosen the ground surface.

Furthermore, if run-off from the stockpiles is uncontrolled, such run-off would likely contain a high sediment load due to the fine particles in the waste product resulting from the ore crushing process. It can thus be stated that without any mitigation measures, the sediment load in the Sterkstroom River will increase as a result of mining activities associated with this Project.

6.2.2 Impaired water quality due to pollutants discharged from mining activities

Unmanaged wastewater from mining related processes would contain pollutants in excess of the target water quality ranges for the water uses of the receiving water body and discharge of this would impact negatively on the surface water quality. A further consideration is the run-off of pollutants from the related process areas following rainfall, due to the activities within that area.

6.2.3 Impaired water quality due to pollutants in run-off from stockpiles

It is likely that run-off from the stockpiles will have a different chemical composition to natural run-off. In this event it is best practice to keep ‘dirty’ water from stockpile run-off separate from ‘clean’ water from natural run-off.

6.2.4 Impaired water quality due to pollutants in water discharged from opencast pits

Overflow of water (decant), whether surface or ground, from the pits could release pollutants to the surface water environment if geochemical testing indicates a possible water quality issue.

6.2.5 Impaired water quality due to petrochemical spills

Fuel or oil spills from vehicles could contaminate surface water resources. Leakages, spills or run-off from vehicle wash bays, workshop facilities, fuel depots or storage facilities of potentially polluting substances could contaminate surface water resources.

6.2.6 Heavy metal contamination

Increase in metal concentrations is commonly associated with tillage and blasting of the upper crust of the earth's surface. This releases metals into the associated surface and ground water systems. This may alter the species composition of the aquatic biota inhabiting the river, in the vicinity downstream of the Tharisa mining study area.

Activities potentially leading to impact

Pre-Construction	Construction	Operational	Decommissioning & Closure
Poor planning leading to extensive and complex dirty water areas which need to be managed.	Major earthworks and construction activities.	Mining and the creation of mining waste which needs to be managed to prevent pollution.	Inadequate closure and rehabilitation leading to ongoing pollution from contaminating sources such as discard dumps.
Poor planning leading to placement of polluting structures in drainage lines which would increase mobility of pollutants.	Clean and dirty water systems not being constructed to the required specifications to prevent contamination of clean water areas.	Clean and dirty water systems not being maintained to the required specifications to prevent contamination of clean water areas.	Clean and dirty water systems not being maintained to the required specifications to prevent contamination of clean water areas.
Inadequate separation of clean and dirty water areas leading to contaminated water leaving the defined dirty water area	Poor housekeeping and management	Poor housekeeping and management	Poor housekeeping and management
Clean and dirty water systems not being designed adequately to ensure protection of the water resources.	Spills and other unplanned events	Spills and other unplanned events	Spills and other unplanned events

Aspects of aquatic ecology affected

Construction	Operational	Decommissioning & Closure
Loss of sensitive fish and aquatic macro-invertebrate species	Loss of sensitive fish and aquatic macro-invertebrate species	Loss of sensitive fish and aquatic macro-invertebrate species due to chronic water quality impacts
Impact on riparian vegetation structures due to impaired water quality	Impact on riparian vegetation structures due to impaired water quality	Impact on riparian vegetation structure due to impaired water quality
Build-up of contaminants in sediments leading to the creation of a sediment sink and chronic source of potential water contamination	Build-up of contaminants in sediments leading to the creation of a sediment sink and chronic source of potential water contamination	Latent release of contaminants in sediments leading to the formation of an ongoing source of potential water contamination
	Impacts on groundwater quality which could manifest in surface water sources	Impacts on groundwater quality which could manifest in surface water sources

Without Management	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
Sterkstroom River	4	4	4	4	5	8	13	104 (Medium-high)

Essential mitigation measures:

- Ensure that as far as possible all infrastructure is placed outside of wetland areas and streams. In particular mention is made of the need to not encroach on the riparian systems on the mine and a minimum buffer of 100m around all wetland and riparian systems should be maintained in line with the requirements of regulation GN704 of the national Water Act.
- Very clear and well managed clean and dirty water separation must take place in line with the requirements of regulation GN704 of the national Water Act.
- Pollution control dams must be adequately designed to contain a 1:50 24 hour storm water event.
- All pollution control facilities must be managed in such a way as to ensure that storage and surge capacity is available if a rainfall event occurs.
- Limit the footprint area of the construction activity to what is absolutely essential in order to minimise the loss of clean water runoff areas and the concomitant recharge of streams in the area.
- Permit only essential construction personnel within 100m of all riparian systems.
- Keep all demarcated sensitive zones outside of the construction area off limits during the construction phase of the development.
- All hazardous chemicals must be stored on specified and regulated surfaces.
- Ensure that all spills are immediately cleaned up.
- Monitor all pollution control facilities using toxicological screening methods and implement the calculation of discharge dilution factors by means of the Direct Estimation of Ecological Effect Potential (DEEEP) protocol.
- Ongoing aquatic ecological monitoring must take place on a 6 monthly basis by an SA RHP Accredited assessor.

Recommended mitigation measures:

- The extent of the operations on Tharisa Mine area, specifically in relation to the Sterkstroom River, must be kept to an absolute minimum.
- No infrastructure or open pits should encroach into any major drainage lines, such as the Sterkstroom River.

With Management	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
Sterkstroom River	4	3	3	3	4	7	10	70 (Medium-low)

Probable latent impacts:

- Ongoing salinisation of the water courses in the area.
- Impacts on pH.
- Impacts on dissolved oxygen concentration and saturation.
- Loss of aquatic taxa intolerant to poor quality water.
- Altered riparian vegetation structures.

6.3 IMPACT 3: Loss of Aquatic Habitat

Habitat destruction is the alteration of a natural habitat to the point that it is rendered unfit to support the species dependent upon it as their home territory. Many organisms previously using the area are displaced or destroyed, reducing biodiversity. Globally modification of habitats for agriculture is the chief cause of such habitat loss. Other causes of habitat destruction include surface mining, deforestation, slash-and-burn practices and urban development. Habitat destruction is presently ranked as the most significant cause of species extinction worldwide. Additional causes of habitat destruction include water pollution, introduction of alien species, overgrazing and overfishing.

Riverine systems and particularly ephemeral riverine systems or river systems that have very low flows as part of their annual hydrological cycles are particularly susceptible to changes in habitat condition. The mining activities of the Tharisa Mine has significant potential to lead to habitat loss and/or alteration of the aquatic and riparian resources on the study area if not managed appropriately.

The risk to the local riverine systems is particularly due to the risk of reduced instream flow in the Sterkstroom River and the loss of refugia during periods of low flow. Based on the historical data provided a limited impact on instream flow is deemed likely however losses of instream flow may affect the aquatic community within the Sterkstroom River and especially fish and aquatic macro-invertebrate species diversity and sensitivity.

Activities leading to impact

Pre-Construction	Construction	Operational	Decommissioning & Closure
Poor planning leading to the placement of infrastructure within riverine features with special mention of the waste stockpile areas and the open pit areas themselves as well as road crossings and bridges	Site clearing and the removal of vegetation leading to increased runoff and erosion	Ongoing disturbance of soils with general operational activities	Disturbance of soils as part of demolition activities
Inadequate design of infrastructure leading to changes to instream habitat	Site clearing and road construction and the disturbance of soils leading to increased erosion	Inadequate separation of clean and dirty water areas	Inadequate separation of clean and dirty water areas
Inadequate design of infrastructure leading to changes to system hydrology	Earthworks in the vicinity of drainage systems leading to increased runoff and erosion and altered runoff patterns	Mining leading to increased disturbance of soils and drainage lines	Ongoing pollution from inappropriately decommissioned structures
Inadequate separation of clean and dirty areas and the prevention of the release of sediment rich water into the receiving environment	Construction of bridge crossings altering streamflow patterns and water velocities	Any activities which lead to the reduction in flow in the system with special mention of the open pits and the use of surface and groundwater sources	Alien vegetation encroachment
	Alien vegetation encroachment	Alien vegetation encroachment	

Aspects of aquatic ecology affected

Construction	Operational	Decommissioning & Closure
Erosion and incision of riparian zone	Erosion and incision of riparian zone	Erosion and incision of riparian zone
Loss of low flow refugia	Loss of low flow refugia	Loss of low flow refugia
Altered substrate conditions from sterkstroom conditions to more muddy conditions	Altered substrate conditions from sterkstroom conditions to more muddy conditions	Altered substrate conditions from sterkstroom conditions to more muddy conditions
Altered depth and flow regimes in the major drainage systems	Altered depth and flow regimes in the major drainage systems	Alien vegetation proliferation
Alien vegetation proliferation	Alien vegetation proliferation	

Without Management	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
Sterkstroom River	4	4	4	3	5	8	12	96 (Medium-high)

Essential mitigation measures:

- Ensure that as far as possible all infrastructure is placed outside of wetland areas and streams. In particular mention is made of the need to not encroach on the riparian systems of the Sterkstroom River within the mine study area and a minimum buffer of 100m around all wetland and riparian systems should be maintained in line with the requirements of regulation GN704 of the national Water Act.
- Limit the footprint area of the construction activity to what is absolutely essential in order to minimise the loss of clean water runoff areas and the concomitant recharge of streams in the area.
- Ensure that all stockpiles are well managed and have measures such as berms and hessian sheets implemented to prevent erosion and sedimentation.
- No use of clean surface water or any groundwater which potentially recharges the watercourses in the area should take place. In this regard specific mention is made of any water use which will affect the habitat in the Sterkstroom River and the associated tributaries.
- Pollution control dams should be off stream structures and not within the natural drainage system of the area, thereby minimising impacts of riparian habitat loss.
- Permit only essential construction personnel within 100m of all riparian systems.
- Keep all demarcated sensitive zones outside of the construction area off limits during the all phase of Tharisa mining operations.
- Implement alien vegetation control program within wetland areas with special mention of water loving tree species.
- Ongoing aquatic biomonitoring should take place in order to identify any emerging issues in the receiving environment. Monitoring should include assessments of general habitat integrity, habitat for aquatic macro-invertebrates and habitat and cover ratings for fish. All aquatic biomonitoring should be undertaken by a SA RHP Accredited assessor. Aquatic biomonitoring should take place throughout the life cycle of the mine.

Recommended mitigation measures:

- The extent of the operations on the Tharisa mining study area must be kept to an absolute minimum.
- No infrastructure or open pits should encroach into any major drainage lines.

With Management	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
Sterkstroom River	3	4	3	2	4	7	9	63 (Medium low)

Probable latent impacts:

- Sedimentation of the systems may occur for long after mining is completed.
- Eroded and incised streams are unlikely to be rehabilitated.
- Ongoing loss of instream flow leading to a loss of low flow refugia.

6.4 IMPACT 4: Loss of Aquatic Biodiversity and Sensitive Taxa

Aquatic resources in the area can be considered scarce and in addition to being scarce are generally exposed to significant water stresses. The aquatic resource in the area do however support, or potentially support, an aquatic community of significant diversity and sensitivity. This statement is considered particularly pertinent to aquatic macro-invertebrates and the fish community. The aquatic ecology and the biological diversity of the area can potentially be impacted by further reductions in instream flow, altered water quality and habitat loss.

Activities leading to impact

Pre-Construction	Construction	Operational	Decommissioning & Closure
Poor planning leading to the placement of infrastructure within riverine features with special mention of the overburden stockpile areas as well as the open pits themselves as well as road crossings and bridges	Site clearing and the removal of vegetation	Ongoing disturbance of soils with general operational activities	Disturbance of soils as part of demolition activities
Inadequate design of infrastructure leading to changes to instream habitat	Site clearing and road construction	Inadequate separation of clean and dirty water areas	Inadequate separation of clean and dirty water areas
Inadequate design of infrastructure leading to changes to system hydrology	Earthworks in the vicinity of wetland and riparian areas	Loss of instream flow due to dewatering from open pits leading to reduced aquifers recharge in the river	Seepage from any latent discard dumps and dirty water areas

Inadequate design of infrastructure leading to contamination of water and sediments in the streams	Construction of bridge crossings altering stream flow patterns and water velocities	Seepage from the discard dumps and overburden stockpiles	Inadequate closure leading to post closure impacts on water quality
	placement of infrastructure within riverine features with special mention of the overburden stockpile areas as well as the open pits themselves as well as road crossings and bridges	Discharge from the mine process water system with special mention of the RWD and any PCD's	Ongoing erosion of disturbed areas that have not been adequately rehabilitated
	Inadequate separation of clean and dirty water areas	Sewage discharge from mine offices and camps	
		Nitrates from blasting leading to eutrophication of the receiving environment	

Aspects of aquatic ecology affected

Construction	Operational	Decommissioning & Closure
Sedimentation and loss of natural substrates	Sedimentation and loss of natural substrates	Sedimentation and loss of natural substrates
Altered stream channel forms	Altered stream channel forms	Altered stream channel forms
Increased turbidity of water	Increased turbidity of water	Loss of refugia
Loss of refugia	Loss of refugia	Deterioration in water quality with special mention of impacts from cyanide, heavy metals, AMD and salinisation
Deterioration in water quality	Deterioration in water quality with special mention of impacts from cyanide, heavy metals, AMD And salinisation	Eutrophication of the aquatic ecosystems
Loss of flow sensitive macro-invertebrates and fish	Eutrophication of the aquatic ecosystems	Loss of flow sensitive macro-invertebrates and fish
Loss of water quality sensitive macro-invertebrates and fish	Loss of flow sensitive macro-invertebrates and fish	Loss of water quality sensitive macro-invertebrates and fish
Loss of riparian vegetation species	Loss of water quality sensitive macro-invertebrates and fish	Loss of riparian vegetation species
	Loss of riparian vegetation species	

With Management	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
Sterkstroom River	4	3	3	4	5	7	11	77 (Medium-high)

Essential mitigation measures:

- Ensure that as far as possible all infrastructure is placed outside of wetland areas and streams.
- Pollution control dams should be off stream structures and not within the natural drainage system of the area, thereby minimising impacts form inundation, siltation and habitat loss.
- Permit only essential personnel within 100m of the wetland habitat.
- Keep all demarcated sensitive zones outside of the area off limits during the construction phase of the development.
- Use of water must be minimised as far as possible in order to minimise the loss of recharge of the Sterkstroom River system.
- Limit the footprint area of activities to what is absolutely essential in order to minimise disturbance of soils leading to runoff, erosion and sedimentation and loss of instream flow and stream recharge.
- Prevent run-off from dirty water areas entering stream systems through ensuring clear separation of clean and dirty water areas.
- Ensure that the mine process water system is managed in such a way as to prevent discharge to the receiving environment and to prevent discharge of dirty water.
- Implement measures to contain seepage as far as possible to prevent contamination of the groundwater regime.
- Implement alien vegetation control program within wetland areas.
- Monitor all systems for erosion and incision.
- Any areas where active erosion is observed must be rehabilitated and berms utilised to slow movement of water.
- Ongoing aquatic biomonitoring should take place in order to identify any emerging issues in the receiving environment. Monitoring should include assessments of riparian vegetation, aquatic macro-invertebrates fish and the associated habitat indices. All aquatic biomonitoring should be undertaken by a SA RHP Accredited assessor. Aquatic biomonitoring should take place throughout the life cycle of the mine.
- Toxicological monitoring of the receiving and process water systems on a quarterly basis.

Recommended mitigation measures:

- The extent of the operations along the Sterkstroom River system must be kept to an absolute minimum.
- No infrastructure or open pits should encroach into any major drainage lines.
- Monitoring of sediment heavy metal concentrations.

With Management	Probability of Impact	Sensitivity of receiving environment	Severity	Spatial scale	Duration of impact	Likelihood	Consequence	Significance
Sterkstroom River	4	3	2	3	4	7	9	63 (Medium-low)

6.5 SUMMARY OF AQUATIC ECOLOGICAL IMPACTS

6.5.1 Impact assessment summary

Based on the above assessment it is evident that there are 4 major impacts on the aquatic ecology on the Sterkstroom River system within the Tharisa Mine study area. The table below summarise the findings indicating the significance of the impact before mitigation takes place and the likely impact if management and mitigation takes place. In the consideration of mitigation it is assumed that a high level of mitigation takes place but which does not lead to prohibitive costs.

Table 8: A summary of the results obtained from the assessment of aquatic ecological impacts on the Sterkstroom River section for the Tharisa Mine study area

Impact	Unmanaged	Managed
1: Loss of instream flow, aquatic refugia and flow dependent taxa	Medium-High	Medium-Low
2: Impacts on water quality affecting aquatic ecology	Medium-High	Medium-Low
3: Loss of Aquatic habitat	Medium-High	Medium-Low
4: Loss of Aquatic Biodiversity and sensitive taxa	Medium-High	Medium-Low

Overall the impact of the Tharisa Mine on the Sterkstroom River and tributaries within the region is considered to be Medium-High. If mitigation takes place, all impacts can be considered to be Medium-Low impacts.

6.5.2 Impacts of specific concern on the Sterkstroom River due to the Tharisa mining operation

Dewatering may be occurring in the Sterkstroom River due to the Hernic open pit (quarry) where the mines closed water system is stored. The 2013 November site visit indicated that no water was identified at the downstream site B1 in comparison to the upstream site A (refer to Figure 3 and 4). The Hernic Quarry currently has a water level which is lower than the level of the adjacent Sterkstroom River. The quarry therefore has the potential to lead to dewatering of the Sterkstroom which could have an impact on the instream and riparian habitat on the areas on the Sterkstroom downstream of this point. In turn impacts on instream flow and habitat has the potential to impact on aquatic and riparian communities.

The interactions between the Hernic Quarry and the Sterkstroom River need to be clearly defined by a suitably qualified geohydrologist.

If the Tharisa Mining operations expand and the mine disposes of more dirty water in the Hernic Quarry this will raise the water level within the quarry. Should this level increase to above the level of the Sterkstroom River a hydraulic head may form which could lead to movement of contaminated water to the Sterkstroom River which could lead to impacts on the local and downstream instream ecology leading to a loss of aquatic biodiversity and general aquatic community sensitivity.

It is important that impacts on the Sterkstroom River and wetland systems are minimised and that mitigation measures are put in place to manage all impacts and minimise the negative impacts on the aquatic ecology of the Tharisa Mine activities and its sphere of influence, whatever their severity to ensure the aquatic ecology is conserved and that the aquatic integrity of the area is kept as intact as possible with special mention of the Sterkstroom River system.

6.5.3 Probable latent impacts throughout all development phases of Tharisa Mine.

- On-going erosion and sedimentation may occur if the riparian areas are not effectively protected affecting biodiversity;
- On-going erosion and sedimentation of the system may lead to altered instream habitat if riparian areas are not effectively protected;
- Ongoing and loss of more sensitive taxa;
- Proliferation of alien and weed species in disturbed areas will lead to altered vegetation communities within the riparian areas if not continually monitored and removed;
- Sedimentation of the systems may occur for long after mining is completed;
- Eroded and incised streams are unlikely to be rehabilitated;
- Ongoing loss of instream flow leading to a loss of low flow refugia;
- Ongoing salinisation of the water courses in the area;
- Impacts on pH;
- Impacts on dissolved oxygen concentration and saturation;
- Loss of aquatic taxa intolerant to poor quality water;
- Altered riparian vegetation structures;
- Dewatering may be occurring in the Sterkstroom River due to the Tharisa mining activities, in-depth investigation by a qualified geohydrologist is recommended;

- The effect of the water table relationship of the Sterkstroom River and the Hernic open pit should be investigated by a geohydrologist to verify what the possible movement potential will be and what impact there could be if the water table in the Hernic pit is higher than the baseflow level of the Sterkstroom River;
- Reduced recharge of the Sterkstroom River and other riparian systems affected by upstream and adjacent mining;
- Reduced availability of refugia for aquatic biota;
- Altered riparian vegetation structures.

7 CONCLUSION AND RECOMMENDATIONS

Concluding synthesis of water quality within the Tharisa study area

The historical baseline documented results for this study area are to be taken from the NSS 2008 report. Overall, the water quality since then (NSS 2010, NSS 2011 and CS 2013) has improved for the pH and DO values since 2008 according to the TWQR guidelines (DWAF 1996 Vol 7) and should not pose a risk to aquatic biota. The EC values however did not improve. Temporally for both upstream and downstream EC values for 2008, 2010, 2011 and 2013 have revealed a marked increase of greater that 15% for each year which is outside the TWQR guidelines in relation to the reference 2008 year. Any additional negative impact on the system resulting in poorer (compared to baseline) water quality conditions, may have significant negative repercussions for the receiving ecosystem. Continued assessments will indicate if such impacts could possibly result from Tharisa mining activities and will allow for proactive mitigation to be implemented

Concluding synthesis of macro-invertebrates within the Tharisa study area

The SASS data indicates that the aquatic macro-invertebrate community in this section of the Sterkstroom River has suffered a general loss in integrity throughout the area, when compared to the reference score for a pristine ecoregion system. Depending on the flow (high flow or low flow) biomonitoring periods the macro-invertebrate community MIRAI and SASS scores at the upstream reference site upstream of the Tharisa mining study area can vary considerably. This fluctuation of macro-invertebrates over the different flow periods can be considered to be natural variation, along with the possible altered water flow from the Bufflespoort dam and may impact on the aquatic community in the Sterkstroom River system. When specifically comparing the macro-invertebrate scores between the upstream and the downstream sites along the Sterkstroom River we find that no significant change in the classes occurred within the study area. Therefore no impact on the macro-invertebrate community is deemed to be taking place from the current Tharisa mining related activities between the upstream and downstream sections assessment.

Concluding synthesis of the fish assemblage within the Tharisa study area

According to the scores, the fish assemblages were moderately modified at both upstream and downstream sites for 2010, 2011 and for 2013 survey periods. These results were primarily due to the lower number of indigenous species present in comparison to the expected fish species, which were based on fish studies conducted in the Sterkstroom catchment. This indicates that activities relating to Tharisa mine have not impacted on the fish assemblage along the Sterkstroom River. Impacts within this river system can be directly related to potential activities that may be affected by Tharisa mining related activities, any change to the water quality and water flow over time may decrease the fish assemblage and close monitoring for this should be implemented throughout all phases of the Tharisa mining operations.

Upon conclusion of the aquatic assessment, the following recommendations are made:

- Toxicity analyses for all the Tharisa mining process water management operations should be conducted. The level of toxicity for these water bodies can be monitored and any risk to the receiving aquatic environment they are directly associated to can be better managed in order to identify potential water quality hazards that may originate from the specific Tharisa mining operations.
- Biomonitoring protocols, as applied in historical studies should be continued in future to verify and identify any biotic responses that may arise from activities at the mine during the all phases. The MIRAI and FRAI methods should also be continued in further biomonitoring reports. This would help with best management practices when potential biotic problems arise. Such a biomonitoring programme should be performed at least twice per annum, once during the dry season and once during the wet season periods.
- All aquatic ecological assessments must be undertaken by South African River Health Program (SA RHP) accredited assessors and it is advised to try and use the same assessor as far as possible to obtain accurate data.
- It is also recommended that historical biomonitoring points be revisited and reused to assure accurate and comparable data sets.
- Toxicity analyses should be performed on all mining effluents (which could potentially be discharged to the receiving environment) and on all PCD's in order to quantify and classify the acute toxicological risk associated with such potential sources of pollution.
- In addition to the historical biomonitoring points, additional points are advised to be utilised especially downstream from the N4 highway development.

- Additional monitoring sites along the Sterkstroom River would be essential to determine if any impact on the systems is occurring through the analyses of spatial and temporal trends in the data.
- Consideration of collection and analysis of Diatom Samples is recommended to be conducted at all biomonitoring sites within the study area. Diatoms are microscopic unicellular algae which grow in a wide range of habitats in damp soils, lakes, rivers and seas. Extremely common in almost all freshwater and marine environments they are excellent ecological indicator species sensitive to acidity, nutrients and salinity. Since they have a short life cycle they respond quickly to changes in conditions. Diatom communities are a popular tool for monitoring environmental conditions, past and present, and are commonly used in studies of water quality (WRC report TT 282/07).
- The interactions between the Hernic quarry and the Sterkstroom River need to be clearly defined by a suitably qualified geohydrologist. To determine the possibility of dewatering taking place as well as the movement of possible contaminated waters to the Sterkstroom River from the Hernic quarry.

8 REFERENCES

Chutter, F. M. (1998). **Research on the rapid biological assessment of water quality impacts in streams and rivers.** Report to the water research commission by Environmentek, CSIR, WRC report No 422/1/98. Pretoria: Government printer

Crafford, D. 2000. **Application of a Fish Health Assessment Index and Associated Parasite Index on *Clarias gariepinus* (Sharptooth Catfish) in the Vaal River System with reference to Heavy Metals.** Rand Afrikaans University, M.Sc. Dissertation

Clean Stream Biological Services (2013). **Tharisa minerals: Sterkstroom catchment biomonitoring programme.** Report reference: TM/A/13

Dickens, C. & Graham, M. (2001). **South African Scoring System (SASS) version 5. Rapid bio assessment for rivers May 2001.** CSIR. http.//www.csir.co.za/rhp/sass.html

Department of Water Affairs and Forestry (1996). **South African water quality guidelines** vol. 7, Aquatic ecosystems

Department of Water Affairs and Forestry. (2003). **The management of complex waste water discharges, introducing a new approach – Toxicity-based Ecological Hazard Assessment (TEHA).** Discussion document, third draft

Kleynhans, CJ (1999). **The development of a fish Index to assess the biological integrity of South African rivers.** Water SA 25(3) 265-278

Kleynhans, C. J. (2002). ***Fish Intolerance ratings.*** Proceedings resulting from the national fish workshop held at the WRC during 2001.

McMillan, P. H. (1998): **An integrated habitat assessment system (IHAS v2) for the rapid biological assessment of rivers and streams.** A CSIR research project. Number ENV-P-I 98132 for the water resources management programme. CSIR. ii +44 pp

NSS (2008). Natural Scientific Services. **Tharisa Minerals Biodiversity Report**. Ref No: 1211

NSS (2010). Natural Scientific Services .**Tharisa Minerals Low Flow Biomonitoring Report**. Ref No: 1486

NSS (2011). Natural Scientific Services .**Tharisa Minerals High Flow Biomonitoring Report.** Ref No: 1486

Skelton, P. H. (2001). **A complete guide to freshwater fishes of Southern Africa.** Southern Book Publishers (Pty) Ltd., Halfway House. 388pp

United States Environmental Protection Agency (US EPA, 1993). **Method for measuring the acute toxicity of effluents and receiving waters to freshwater and marine**

organisms. EPA/600/4-90/027F, 4th Edition. Office of Research and Development, Washington DC 20460

United States Environmental Protection Agency (US EPA, 1996). **Ecological effects test guidelines.** Fish acute toxicity test, Freshwater and marine. OPPTS 850.1075. Report number EPA-712-C-96-118

WRC report TT 282/07: **A Methods Manual for the Collection, Preparation and Analysis of Diatom Samples.** Version 1.0