INKOMATI-USUTHU

CATCHMENT MANAGEMENT AGENCY

DETAILED MONITORING OF RIVER CONDITIONS IN THE UPPER SABIE RIVER CATCHMENT 2014

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Vision

Water for all in Inkomati

Mission

Our mission is of a pioneering catchment management system that empowers stakeholders to engage in consensual and adaptive decision making, to achieve reform, and to promote persistent social, economic and environmental justice across the Inkomati catchment.

- The Inkomati CMA supports the co-operative management of the Inkomati basin as an internationally shared water course
- The decision-making environment of the Inkomati CMA, including delegated functions, enables collaborative action towards equity, sustainability and efficiency in a continually evolving socio-economic system.
- The Inkomati CMA manages the resources adaptively, co-operatively and progressively to achieve social, economic and environmental justice, and promote healthy living.

Our Values

- The Inkomati CMA acknowledges the interdependence of our responsibilities for caring for the resource and there is explicit recognition of the diversity achieved by what individual/ group contributes to promoting equity, efficiency, and sustainability as defined in the National Water Act.
- Decisions, actions and outcomes are subject to performance evaluation against measurable goals, indicators and timeframes.
- The Inkomati CMA strives for a trusting, transparent and corrupt-free system of catchment management that is cognisant of existing agreements and promotes fairness before the law, environment and economic development.
- Management is adaptive, open to critique and outcomes driven, with solutions being practical, achievable and implementable.
- The Inkomati CMA practices problem solving that embraces:
- Ethics of Ubuntu (out humanity is defined by how others experience our behaviour), Simunye (we are one) and Batho-pele (people first)
- Consensus driven stakeholder participation
- Decision within our mandate are made and are justified on the basis of the best available social, technical, economic, environmental and governance knowledge.

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Cover Photo: View of the Sabie River at Rietfontein Mine during high and low flow

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List of Abbreviations

BNF	=	Buffered Neutral Formalin
CPUE	=	Catch Per Unit Effort
DEWA	=	Department of Environmental and Water Affairs
DWA	=	Department of Water Affairs
EC	=	Electrical Conductivity
EIS	=	Ecological Importance and Sensitivity
FRAI	=	Fish Response Assessment Index
ICMA	=	Inkomati Catchment Management Agency
IWQS	=	Institute for Water Quality Studies
KLF	=	Komatiland Forests
MTPA	=	Mpumalanga Tourism and Parks Authority
NCMP	=	National Chemical Monitoring Programme
PES	=	Present Ecological Status
SWWTW		Sabie Waste Water Treatment Works
USM	=	Upper Sabie Project Monitoring Point

1. INTRODUCTION

In 2010/11, considerable deterioration of the Sabie River above and below Sabie Town was reported based on an assessment of the ecological status of the Sabie-Sand Catchment. In 2002, based on biological indicators, the ecological status of the upper Sabie Catchment was categorised as Good (B-class).The 2010/11 survey revealed that the ecological status had deteriorated to Fair-Poor (C/D-class). Reasons for this deterioration were listed as impacts associated with excessive sedimentation, reduced water quality and introduced trout (MTPA 2011).

Commercial forestry is the main land-use in the upper catchment. The entire catchment burnt down in 2007, with several areas scorched due to the high intensity of these uncontrolled fires. Due to the high fuel loads in commercial forestry areas, fire intensity is considerably higher in these areas than in natural grasslands. The soil erosion from these scorched areas after rainfall events was extreme. Soil losses of 1 mm/ha equals 10 m^3 or 3.5 tons of soil.

High road network densities in the commercial forestry areas increase catchment drainage density, which alters the hydrology of the catchment (Harris et al. 2008; Haskins & Mayhood 1997; Jones et al. 2000; Mesa 2010; Wemple et al. 1996; Wemple et al. 2001). During high rainfall events, poor road drainage allows for high volumes of silt laden storm-water run-off to enter stream systems (Anderson 1996; Furniss et al. 1998; Kreutzweiser et al. 2005b; Meghan & Kidd 1972; Reid & Dunne 1984; Sheridan & Noske 2007). High road network densities with high intensity fires in commercial forestry areas are therefore a considerable threat to receiving aquatic ecosystems.

High sediment deposition potentially has major implications for river health. Apart from smothering the habitats, and abrasion during suspension (high flows), it also traps organic material which is abundant in these commercial forest dominated catchments. The trapped organic materials are associated with anaerobic decomposition, which affects the aquatic community (Eriksen 1963; Meyer 1980; Graça 2001; Kaller & Hartman 2004). High organic inputs from sewage, saw-mill sawdust and waste, trout farm dams and other sources will further add to organic loads and increased pressure on the system.

Exotic fish, especially predacious fish species such as rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*), can have considerable impacts on indigenous fish species, frogs, aquatic invertebrates and trophic cascades (Buria et al. 2007; Cucherousset & Olden 2011; McIntosh & Townsend 1996; Mitchell & Knouft 2008; Pace et al. 1999; Young et al. 2010). Trophic cascades are defined as 'reciprocal predator-prey effects that alter the abundance, biomass or productivity of a population community or trophic level across more than one link in a food web' (Pace et al. 1999). The continuous stocking of rainbow trout (*Oncorhynchus mykiss*) in the upper Sabie River is ensuring exotic predators are continuously added to a system with no insight or understanding of the impacts or implications these introductions have on the indigenous aquatic fauna and the ecological functioning of these systems.

Focusing on the three listed impacts raised in the MTPA 2011 report, additional monitoring was proposed aimed at identifying and quantifying specific sources of pollution where possible. The Aquatic Division of Mpumalanga Tourism and Parks Authority (MTPA) was approached by the ICMA to provide a detailed assessment of the Upper Sabie River Catchment. Environmental Biomonitoring Services was approached to assist with this study. In order to achieve this, the following steps were taken:

Determine road and stream network densities of catchment draining commercial forestry areas. Linked to soil erodibility, this information will provide a platform to set priorities in terms of identifying sources of sediment pollution during rainfall events and mitigation measures;
Collect water chemistry samples from the main Sabie River and its tributaries from headwater to the Mac-Mac / Sabaan confluence during high and low flow;
Collect sediment samples from selected points along the Sabie River from headwaters to the Mac-Mac / Sabaan confluence during low flow conditions;
Collect crabs at selected points along the Sabie River during high and low flow to determine the degree of peritrichous ciliate, motile protozoans and bacteria infestations on the gills of these crabs;
A survey of fish species at selected sites during high and low flow conditions to determine the changes in community composition along the river continuum.

2. STUDY AREA

The Upper Sabie Catchment consist of the Sabie catchment upstream from the Mac-Mac/Sabaan confluence, as well as the Mac-Mac and Sabaan catchments (Figure 2-1). Several tributaries feed into the Sabie River between the two monitoring points, of which most drains commercial forestry plantations. Commercial forestry is the dominant land-use (70.1%) in the Upper Sabie Catchment. Other land-uses include urban areas, saw-mills, forestry offices and buildings, natural vegetation, agricultural crops and illegal mining.

A table summarising the area and percentage of each land-use within the Upper Sabie Catchment in 1994 is included below. The Sabie River above the Sabie Falls is currently stocked with rainbow trout (*Oncorhynchus mykiss*). Historically small farm dams were stocked with large-mouth bass (*Micropterus salmoides*) and the Sabie River with brown trout (*Salmo trutta*).

Table 2-1: Area and percentage of land-use in the Upper Sabie Catchment in 1994 (Everard et al. 1994).

Land-use	Area (ha)	Catchment %
Commercial Forestry	109,800	70.1
Natural Vegetation	37,473	23.8
Agricultural Crops	6,547	4.2
Urban, Buildings, Forestry Offices	2,561	1.6
Saw-mills	452	0.3
TOTAL	**157,498**	

Illegal mining has recently become a problem, with records of illegal mining mainly in the upper reaches of the Sabie Catchment, and the Spitskopspruit above Spitskop saw-mill. There is also currently legal mining taking place on a tributary of the Sabie River on the farm Rietfontein 193 JT portion 4. Old abandoned mines are located in the Klein Sabie catchment, and the Rietfontein Mine downstream from the Sabie Sewage Works.

A total of 31 monitoring site s were selected on the Sabie River and its major tributaries, based on perceived point source and non-point source impacts. A

schematic drawing roughly indicating site locations are included in Figure 2-1. A table with detailed information on site locations are included in Table 2-2.

Table 2-2: List of sampled sites, indicating site numbers, location and type of monitoring carried out. Site are listed from the top to the bottom of the catchment.

SITE NO.	SITE NAME	RIVER	ELEVATION	CO-ORDINATES[1]		INDEX			
				LAT (S)	LONG (E)	CHEMICAL	FISH	CRABS	SEDIMENTS
USM 31	Sabie Headwaters	Sabie	1850 - 1870	-25.14559	30.62846	T		D	W
USM 30	Long Tom		1210 - 1230	-25.14433	30.67100	T			W
USM 29	Jantjiesbos	Jantjiesbos	1200 - 1120	-25.14028	30.67548	T			W
USM 28	Above Horseshoe Falls	Sabie	1170 - 1190	-25.13610	30.68400	T			W
USM 27	Weber'sSpruit	Weber'sSpruit	1100 - 1120	-25.12936	30.67744	T			W
USM 26	Below Horseshoe Falls	Sabie	1090 - 1110	-25.12815	30.69890	T			W
USM 25	Sabieshoek		1060 - 1080	-25.12089	30.71704	T		D	W
USM 24	Lone Creek	Lone Creek	1040 - 1060	-25.11791	30.72401	T			W
USM 23	Manyeleti	Manyeleti	1040 - 1060	-25.11725	30.73225	T			W
USM 22	Above York Sawmill	Sabie	1020 - 1040	-25.10714	30.74479	T			W
USM 21	Bridal Veil	Bridal Veil	1010 - 1030	-25.09678	30.74818	T			W
USM 20	Below Horseshoe Falls	Sabie	1000 - 1020	-25.09844	30.75457	T			W
USM 19	Vertroostings	Vertroostings	980 - 1000	-25.09358	30.77103	T			W
USM 18	Klein Sabie	Klein Sabie	980 - 1000	-25.08796	30.77839	T			W
USM 17	Sabie Sewage Farm	Sabie	940 - 960	-25.09145	30.79491	T	F	D	W
USM 16	Spitskopspruit	Spitskopspruit	940 - 960	-25.09519	30.80553	T			W
USM 15	Above Rietfontein Mine	Sabie	920 - 940	-25.09254	30.81338	T			W
USM 14	Rietfontein Mine		900 - 920	-25.07938	30.82638	T	F	D	W
USM 13	Coopers Creek	Coopers Creek	900 - 920	-25.07868	30.82701	T			W
USM 12	Malieveld	Malieveldspruit	920 - 940	-25.07919	30.84692	T			W
USM 11	DR de Wet	DR de Wet	820 - 840	-25.05744	30.87718	T			W
USM 10	DR de Wet-Sabie	Sabie	790 - 810	-25.06027	30.88765	T			W
USM 9	Goudstroom	Goudstroom	800 - 820	-25.07073	30.90130	T			W
USM 8	Frankfort Bridge	Sabie	780 - 800	-25.06219	30.90786	T	F		W
USM 7	KaMahukwane	KaMahukwane	760 - 780	-25.04072	30.92225	T			W
USM 6	Lunsklip	Sabie	710 - 730	-25.04839	30.93100	T		D	W
USM 5	Buffelspruit	Buffelspruit	760 - 780	-25.05667	30.93450	T			W

[1]MapDatum WGS84, Decimal Degrees

SITE NO.	SITE NAME	RIVER	ELEVATION	CO-ORDINATES[1]		INDEX			
				LAT (S)	LONG (E)	CHEMICAL	FISH	CRABS	SEDIMENTS
USM 4	Sabaan	Sabaan	500 - 520	-25.03042	31.02494	T			W
USM 3	Mac-Mac	Mac-Mac	500 - 520	-25.02961	31.02558	T			W
USM 2	Brandwag	Sabie	500 - 520	-25.03008	31.02536	T	F		W
USM 1	Aand-de-Vliet		480 - 500	-25.02840	31.05161	T	F	D	W

SCHEMATIC DRAWING -UPPER SABIE CATCHMENT: USM Monitoring Site Locations

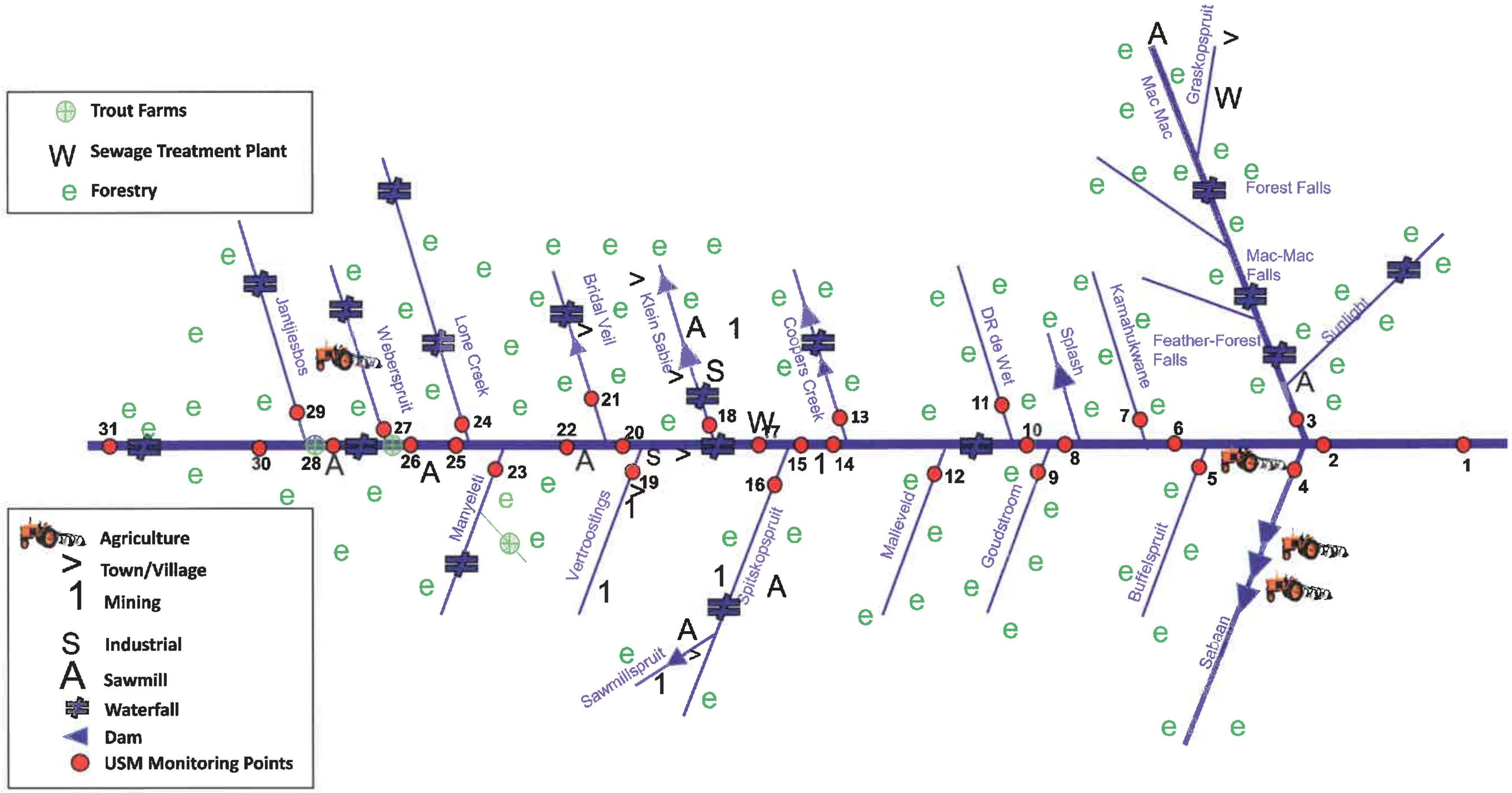


Figure 2-1: Schematic drawing roughly indicating USM site locations for the detailed monitoring of the Upper Sabie Catchment.

3. METHODS

Approach

The following approach was recommended in order to highlight site specific and catchment problems:

Sedimentation

- Calculate road network densities in commercial forestry areas. High road network densities are linked to alterations in catchment hydrology, and sources of excessive sediment inputs into mountain streams;
- Determine particle size distribution of sediment deposits at sites in the river/stream channel.

Water Quality

- Review water quality data from DWAF gauging weirs to determine long term changes in water chemistry;
- Chemical water quality sampling during high and low flows;
- Determine the % carbon in each sediment sample.

Biota

- Fish species surveys to determine changes in fish communities compared to available historical data, and
- Determining microbial gill infestations in crabs within the system, in order to determine the degree of peritrichous ciliate, motile protozoans and bacteria infestations on the gills of collected crabs during high and low flow conditions.

3.1 SEDIMENTS

GIS information from the forestry companies will be gathered to identify the percentage catchment areas that annually experienced uncontrolled fires. Stream network and road network densities will be calculated for each sub-catchment. This information will quantify the changes in catchment drainage density, and potential sources for high sediment inputs int o the river systems. Such information could provide the forest industry with focus areas to resolve sources of sediment pollution.

Sediments were collected during low flow conditions (September 2013) from pool areas in the main river channel at each site. Sediment samples were analysed by Labserve Analytical Services in Nelspruit for particle size composition and organic carbon content. Organic carbon content was analysed to provide a rough indication of the distribution of organic material trapped in the river sediments along the river's continuum.

3.2 WATER QUALITY

Water quality variables are measured weekly to monthly across the country by the Department of Water Affairs as part of the National Chemical Monitoring Programme. This monitoring programme has been in operation since the early 1970's, with samples collected analysed by the laboratory of the Institute for Water Quality

Studies (IWQS). The data collected are stored on DWAF's database Water Management information system (Hohls et al. 2002).

Data for two sampling stations relevant to this study of the Upper Sabie Catchment were downloaded from a website [2] with "cleaned" data [3] in spreadsheets that ranges from October 1976 to December 2011. The one site is located in the town of Sabie on the Sabie River upstream from the Sabie Waterfall, and the other on the Klein Sabie River which is also lo cated at the Sabie Waterfall. The data from these two sites was downloaded and graphs generated to determine trends.

Water samples were collected at all 31 sampling points during high flow (February 2013) and low flow (September 2013) conditions. Water samples were collected infield in treated 1L plastic bottles supplied by WaterLab (Pty) Ltd, kept on ice and delivered to the laboratory the next day.

Water samples were analysed for:

- pH;
- Electrical conductivity (mS/m);
- Chloride (Cl) in mg/ℓ;
- Sulphate (SO_4) in mg/ℓ;
- Nitrate (NO_3) in mg/ℓ;
- Nitrite (NO_2) in mg/ℓ;
- Ortho Phosphate (P) in mg/ℓ;
- Chemical Oxygen Demand (COD) in mg/ℓ;
- E. Coli in parts/100 mℓ
- Free & Saline Ammonia (NH_3) in mg/ℓ;
- Sodium (Na) in mg/ℓ;
- Copper (Cu) in mg/ℓ;
- Iron (Fe) in mg/ℓ, and;
- Manganese (Mn) in mg/ℓ.

3.3 BIOTA

Six sites on the Sabie River were surveyed for fish and six for crabs (Potamonautidae) during high and low flow conditions.

3.3.1 Fish

A detailed fish survey were carried out over two seasons (high and low flow) focusing on the presence and absence of fish species and their abundances. The general approach used for this study was based on the rapid appraisal methods recommended by the Department of Water Affairs and Forestry in their guidelines for Resource Directed Measures for the Protection of Water Resources. The fish assessment aimed to measure present biological conditions and trends in the Sabie River and relate the observed variation to changes in available habitat. The purpose

[2] www.waterscience.co.za/waterchemistry/data.html

[3] Data cleaned and entered into Microsoft Excel spreadsheets by Prof Jan Marten Huizenga, University of the North-West.

was to use resident fish species to characterise the existence and severity of impairments in the Sabie River and identify any sources and causes of impairment related to the catchment.

Reference condition for fish species in the Sabie River was based largely on previous studies (Gaigher 1969, Skelton 1993, Jubb 1967), National River Health surveys (2004 surveys), the former Transvaal Directorate of Nature Conservation Database and experience. The presence, absence or abundance of taxa in comparison to the expected reference condition was therefore based on the available data. The Present Ecological Status (PES) / Ecological Importance and Sensitivity (EIS) Front End Model was used to derive reference species and frequency of occurrence per stream-quaternary reach (DWA, In prep).

Fish were sampled using a 10 mm-mesh scoop-net and a SAMUS DC electro shocking device. Electro shocking is highly ef fective and entails the use of an electronic device to rapidly catch fish. All fish species were identified and abundance assessed (CPUE – catch per unit effort), as well as anomalies and general age structure recorded. Sampling effort was kept to approximately 30 minutes, but variations in time was influenced by stream size and available habitat.

Fish assemblage diversity and abundance vary depending on the season and the integrity of the available habitat. This data was used in the Fish Response Assessment Index (FRAI) to evaluate changes from reference conditions. The FRAI is a rule-based model recently developed by the Department of Environmental and Water Affairs (DEWA) (Kleynhans 2007; Kleynhans et al. 2007a).

3.3.2 Crabs (Potamonautidae)

A study on the degree of peritrichous ciliate, motile protozoans and bacteria infestations on the gills of crab in the polluted rivers of Gauteng correlated with high organic pollution (Schuwerack et al. 2001). High sediment deposition generally traps organic loads, and crabs were considered as a possible indicator of organic pollution in the Upper Sabie River.

Crabs (*Potamonautes sidneyi*) were collected infield at six sampling points in the Sabie River, representing a coverage down the river continuum. Crabs were collected during the high flow (March 2013) and low flow (September 2013) seasons. Six crabs were collected per site (total of 36 individuals) and packed alive in moist Styrofoam crates and couriered to the University of the Free State for examination. Crabs were externally examined for any symbionts. The gill filaments were removed and examined using a dissecting microscope. Sections of the gill lamellae were also placed on microscope slides and examined using a compound microscope. This was the only way to detect the presence of any ciliates. Digital images wer e taken of live observations of both the rotifers and ciliates found.

Rotifers found were fixed in 70% ethanol, and 4% or 10% buffered neutral formalin (BNF). The few ciliates colonies that were found were fixed 10% BNF and/or Bouins and then transferred to 70% ethanol. Sections of the gills were prepared for Scanning electron microscopy, using standard methods. Some of the ciliates were stained using Mayer's Haematoxylin in order to observe internal structures.

In order to determi ne the infestation levels, a scale was used quantify the number of symbionts found. A 1x represents less than 20 individual rotifers per gill filament, 2x represents a higher infestation and 3x was when the entire gill arch was covered by rotifers. The rotifer symbionts were not found on the gill lamellae, but were concentrated on the anterior and posterior margin of the gill arch. Notes were also made if all of the 12 gill filaments per crab were infested or not. The percentage of cover per gill arch was determined by counting the individual specimens per arch (after fixation). In the case of the ciliates, the colonies we encountered were counted. Crabs from the different sites were kept separate.

The data collected on the crabs were summarised per site and per season. This information will provide an indication whether organic material trapped (high sediment inputs) and catchment pollution manifests as a gill infestation response in the crabs collected.

4. ASSUMPTIONS AND LIMITATIONS

Reference conditions are unknown:

The composition of aquatic biota in this study area prior to the previous disturbances or impacts will never be known for certain because there is limited data available prior to the disturbances occurring. For this reason, reference conditions are hypothetical, and are based on professional judgement and/or inferred from data available.

Temporal variability:

The full extent of the natural and seasonal variation in the diversity and abundance of aquatic biota found in the study area is not fully recorded and can have an influence on the results.

Focus of study:

The study focused on crabs and fish and their habitat requirements. This study excludes important life forms such as diatoms, algae, amphibians, reptiles, mammals and birds that may contribute to a more complete description of the system. However, this is not considered necessary for the purpose of this study.

***Impacts overlooked*:**

This study assumed the response of the biota sampled would reflect the impacts on the aquatic environment. This will be true for most of the time, but there may be subtle but significant differences in how the aquatic ecosystem in the area responds to the impacts. There may therefore be a number of potential impacts that were overlooked in this study.

5. RESULTS

Results of sediment samples collected during low flow and analysed by Labserve Analytical Services are included in Appendix B, and illustrated graphically in section 4.1.

The chemical water quality results from WaterLab for both the high and low flow periods are included in Appendix C. The graphs presenting historical results from the National Chemical Monitoring Programme (NCMP) at the Sabie Falls and Klein Sabie gauging stations are included in section 4.2. Results from water samples collected in 2013 during high and low flow are also presented.

The specialist report on the analysis of the gills from crabs collected along the river continuum are included as Appendix D.

The specialist report on the high- and low-flow fish surveys is included as Appendix E.

5.1 ROAD NETWORK DENSITY & RIVER SEDIMENTS

Road network densities per catchment for the major tributaries from commercial forestry areas are presented.

Results from sediment samples indicating particle size distribution and the percentage carbon content are also presented.

5.1.1 ROAD NETWORK DENSITIES

The stream network densities are summarised per tributary sampled during the monitoring of the Upper Sabie Catchment in 2013. The road network densities, based on data made available by the forestry companies, are also included. Catchment drainage density are summarised.

The information in the table will be completed as soon as it is available from the forestry companies. Existing data in the table were generated from data supplied by Komatiland Forests (KLF).

Table 5-1: Road and stream network densities, catchment drainage density and the number of stream crossings in the upper catchment of sampling points.

SITE	RIVER / STREAM	CATCHMENT AREA (ha)	STREAMS (m)	ROADS (m)	NO. STREAM CROSSINGS	DRAINAGE NETWORKS DENSITY		C = S + R
						Streams (S)	Roads (R)	Catchment (C)
USM 31	Sabie							
USM 30	Sabie	1,770	41,045		144	23.2		
USM 29	Jantjiesbos	1,640	29,035		75	17.7		
USM 28	Sabie							
USM 27	Weber's Spruit	1,310	34,115		76	26.0		
USM 26	Sabie							
USM 25	Sabie							
USM 24	Lone Creek	2,770	68,530		196	24.7		
USM 23	Manyeleti							
USM 22	Sabie							
USM 21	Bridal Veil	1,870	44,246		119	23,7		
USM 20	Sabie							
USM 19	Vertroostings							
USM 18	Klein Sabie	3,960	76,523[4]		143	19.3		
USM 17	Sabie							
USM 16	Spitskopspruit	3,470	43,464		175[5]	12.5		
USM 15	Sabie							
USM 14	Sabie							
USM 13	Coopers Creek	1,370	18,750		39[6]	13.7		
USM 12	Malieveldspruit	1,860	39,918		252	21.5		
USM 11	DR de Wet	870	26,251		76	30.2		
USM 10	Sabie							
USM 9	Goudstroom	2,480	66,744		440	26.9		
USM 8	Sabie							
USM 7	KaMahukwane	690	14,889		113	21.6		
USM 6	Sabie							
USM 5	Buffelspruit							
USM 4	Sabaan	600	17,022		39	28.4		

[4]Excluding Simile Township and Klein Sabie Industrial Area.
[5]Only KLF data
[6]Only KLF data

USM 3	Mac-Mac							
USM 2	Sabie							
USM 1	Sabie							
TOTAL								

5.1.2 SEDIMENT SAMPLES

5.1.2.1 Particle Size Distribution

Sediments were collected from pool areas in the main stream channel. Particle size distribution in the laboratory was divided as follows:

> 2 mm;
2.0 – 1.4 mm;
1.4 mm – 600 µm;
600 – 355 µm;
355 – 212 µm;
212 – 38 µm, and
< 38 µm.

The results for sites on the Sabie River are illustrated in Figure 5-1, and for sites on tributaries in Figure 5-2.

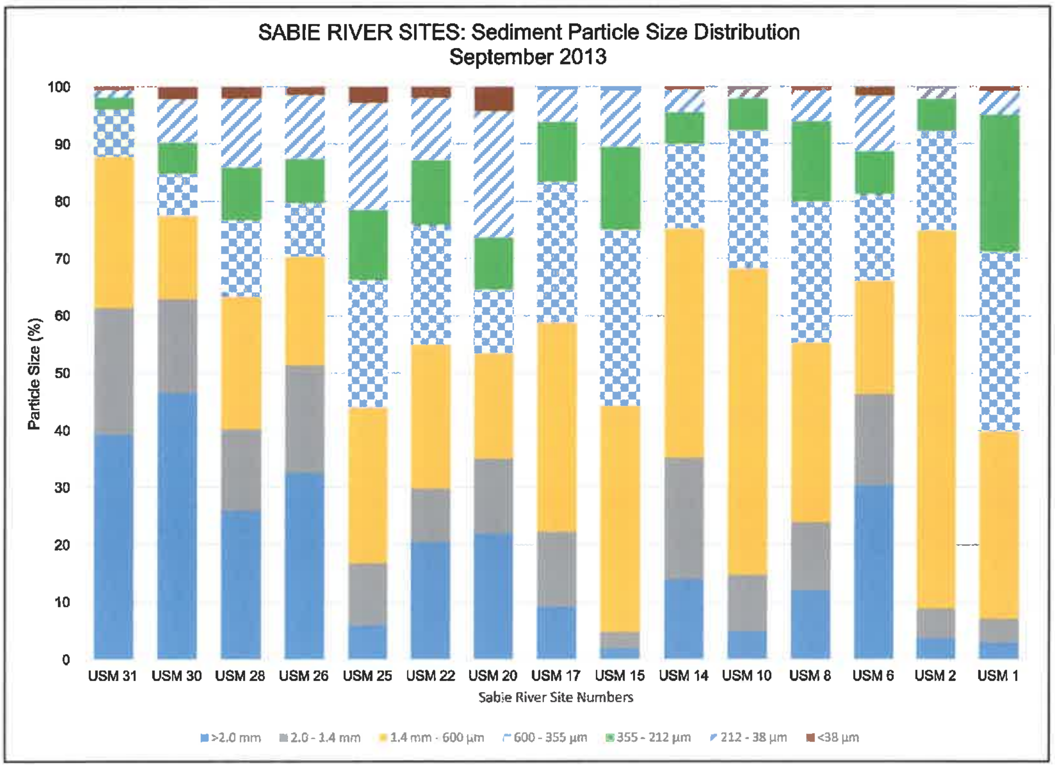


Figure 5-1: Particle size distribution of sediment samples at sites sampled in the Sabie River from Sabie Headwaters (USM 31) to Aand-de-Vliet (USM 1).

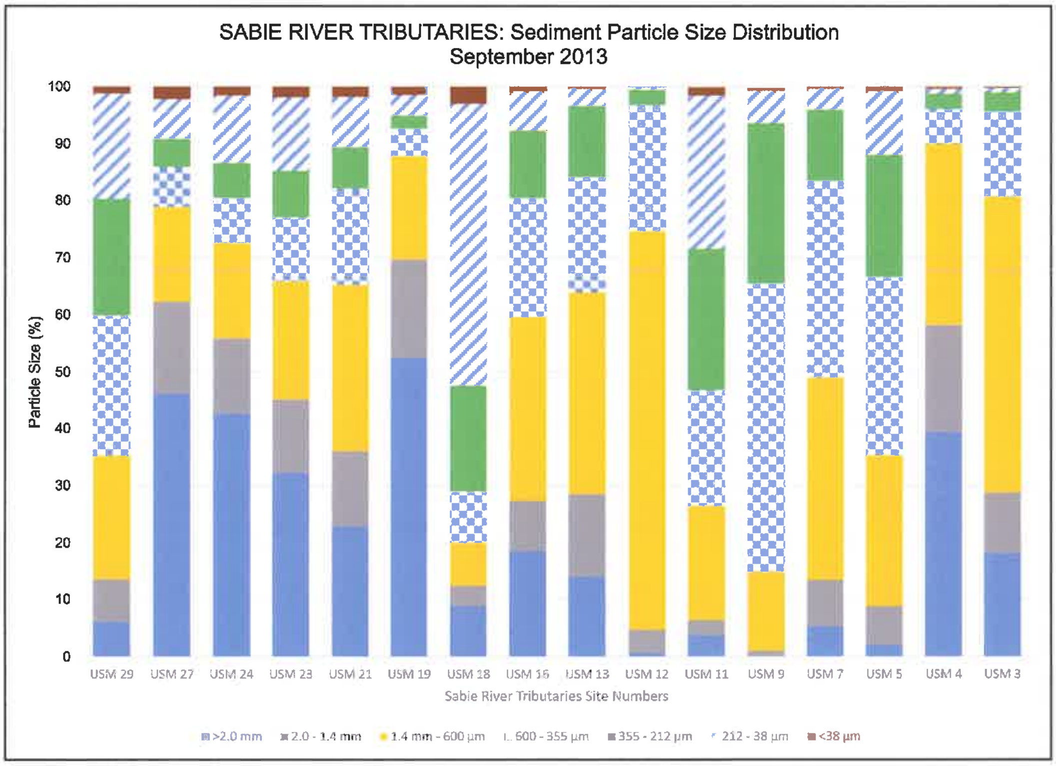


Figure 5-2: Particle size distribution of sediment samples at sites sampled in the tributaries of the Sabie River from Sabie Headwaters (USM 31) to the Mac-Mac (USM 3).

5.1.2.2 Percentage (%) Carbon in Sediments

The carbon content of sediment samples were determined in the laboratory, and are illustrated for sites along the main Sabie River (Figure 5-3) and for sites on tributaries of the Sabie River (Figure 5-4).

The carbon content, as expected, a re generally high in the headwaters decreasing further downstream. In the Sabie River, the Sabie-Headwaters (USM 31) and Lunsklip (USM 6) sites stands out as outliers.

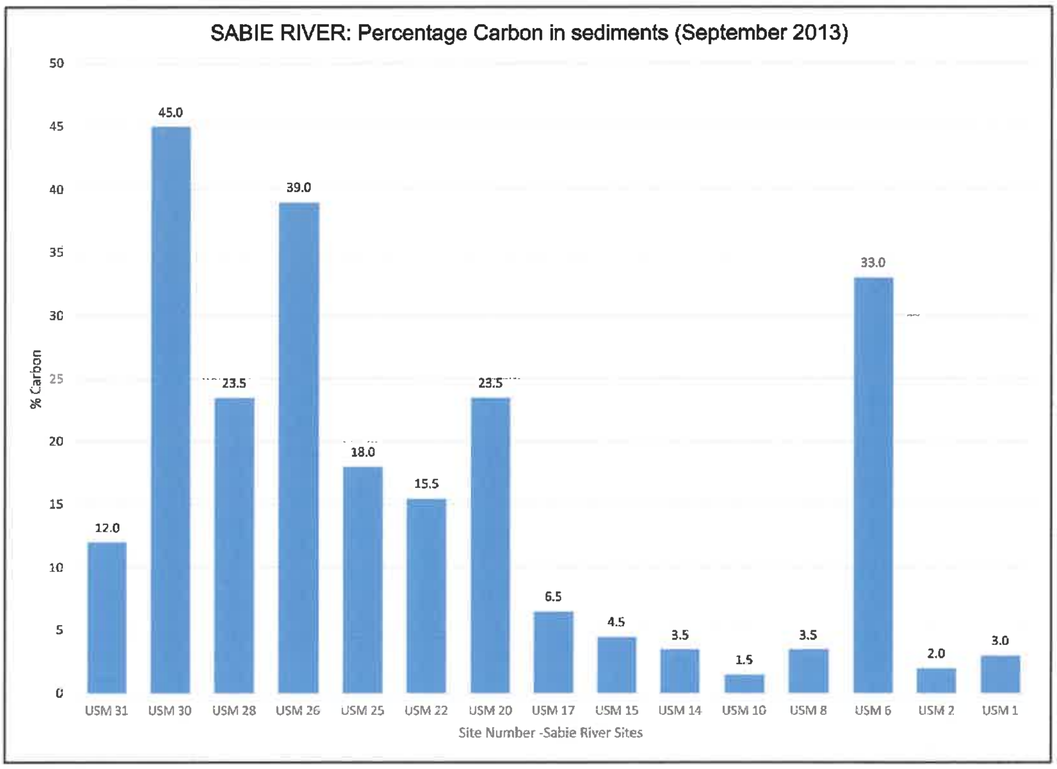


Figure 5-3: The percentage carbon along the Sabie River illustrated per sampling point from Sabie Headwaters (USM 31) to Aand-de-Vliet (USM 1).

In the Sabie Tributaries, the percentage carbon content per site also decrease along the river continuum. The Jantjiesbos (USM 29) and DR de Wet stream (USM 11) stands apart from the rest of the results.

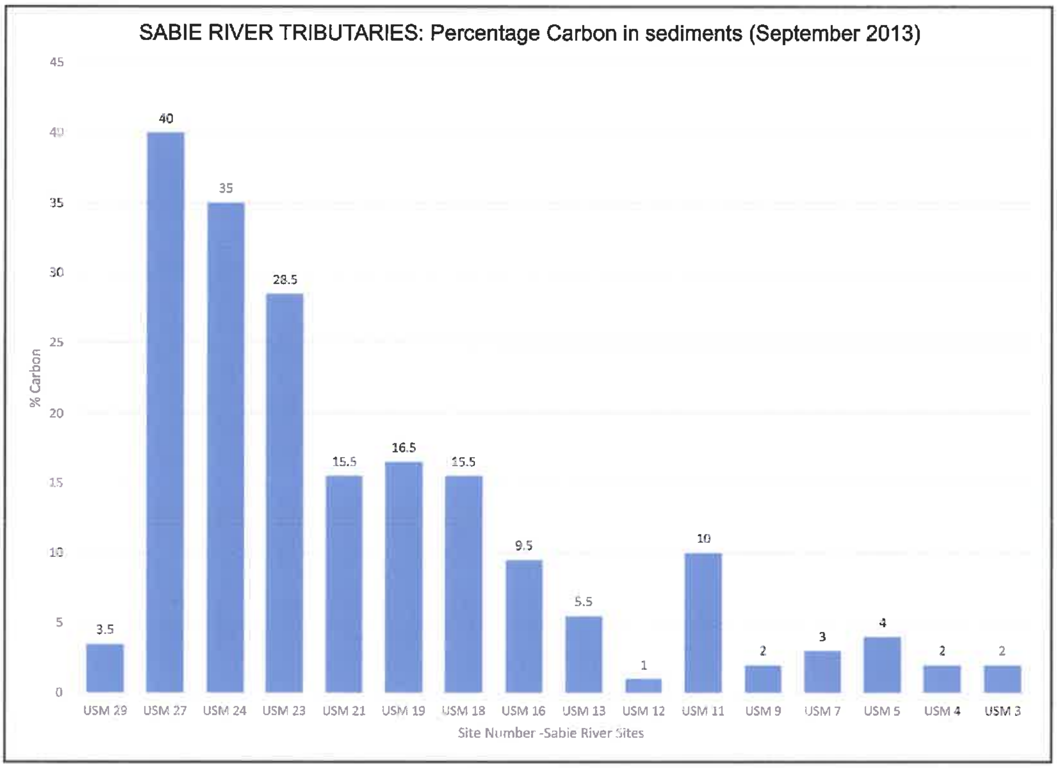


Figure 5-4: The percentage carbon along the tributaries of the Sabie River illustrated per sampling point from Sabie Headwaters (USM 31) to Mac-Mac (USM 3).

5.2 WATER QUALITY ANALYSIS

Of the 31 sites sampled, 15 are located on the Sabie River from its headwaters (USM 31) to Aand-de-Vliet (USM 1). The remaining 16 sites are located on some of the Upper Sabie Rivers' major tributaries. Graphical illustrations of the results are presented separately for sites on the main Sabie River and its tributaries. Results from the general water quality parameters analysed by Waterlab (Pty) Ltd are attached as Appendix C. Water clarity results of measurements taken infield with a 120 cm turbidity tube are also included.

5.2.1 pH

Results are graphically illustrated for sites located in the main Sabie River from Headwaters (USM 31) to Aand-de-Vliet (USM 1) and for tributaries of the Sabie River from headwaters to the Mac-Mac confluence.

Based on historical (1976-2010) pH values measured at the Sabie Falls Gauging station, pH increase during low flow conditions and decrease during high flow conditions (Figure 5-5). Highest seasonal pH values were initially measured over June, later on towards July and more recently in August. The lowest pH values varied between the months of January, February and March. The historical results indicate a steady increase in pH values since the first pH values was measured in 1976.

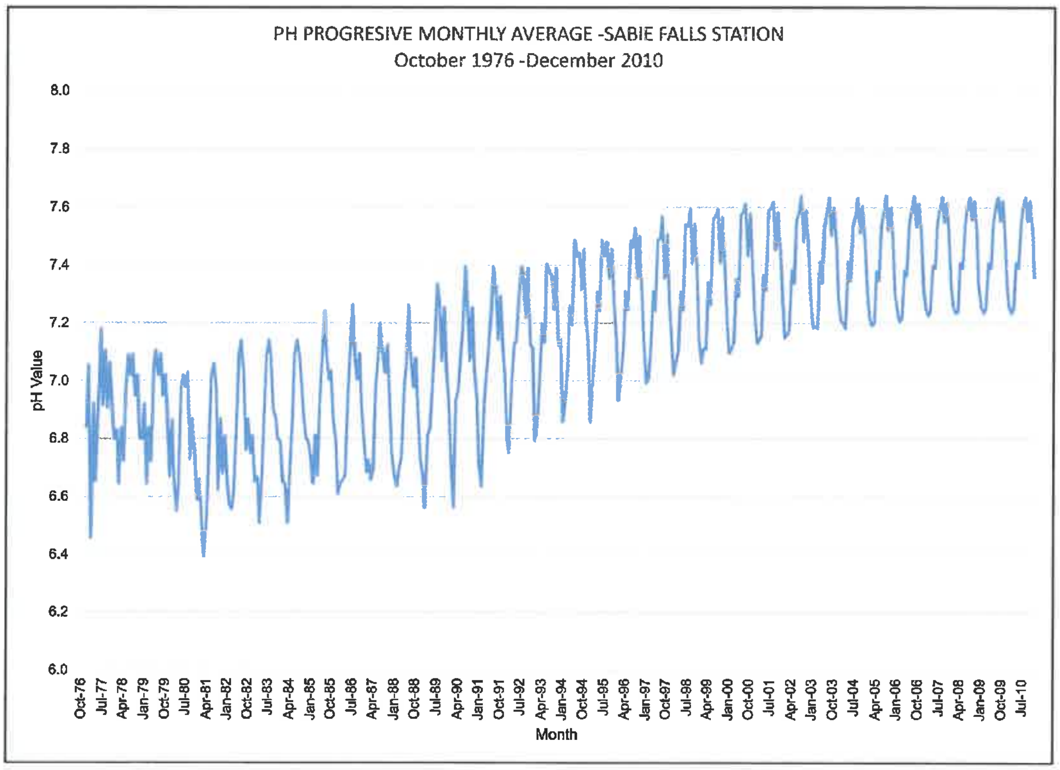


Figure 5-5: The progressive monthly average pH values measured at the Sabie Falls Gauging station from October 1976 to December 2010.

The average pH values for from October 1976 to December 1979 are considerably lower than those averages recorded from January 2000 to December 2009 (Figure 5-6).

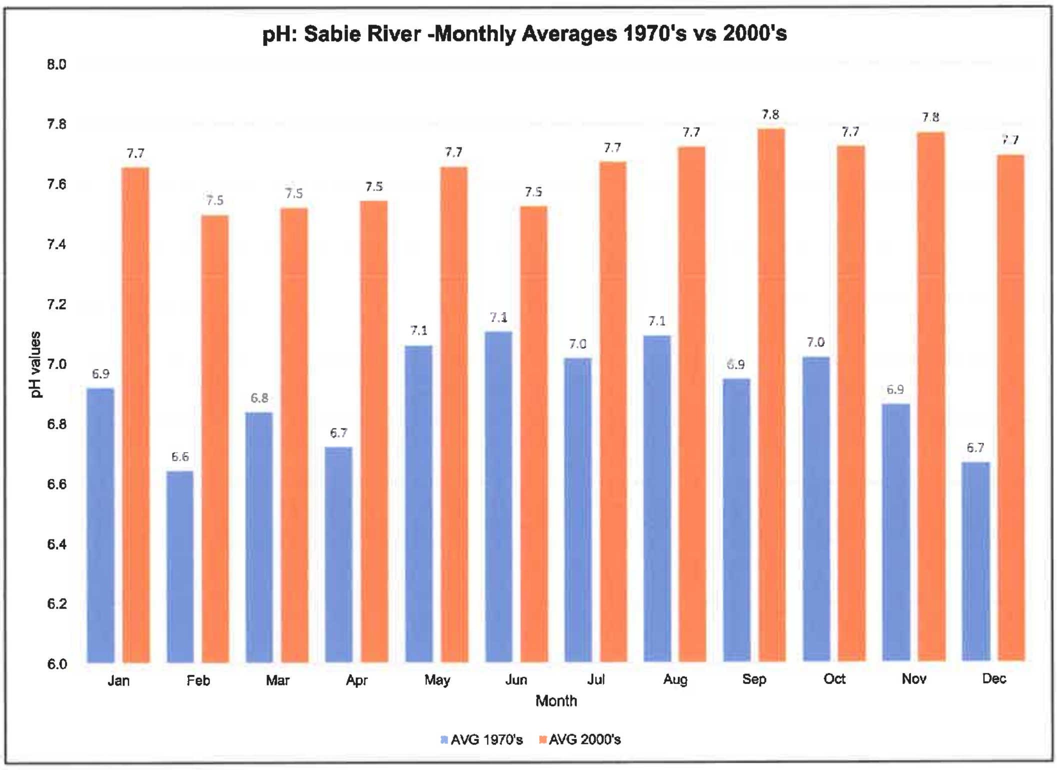


Figure 5-6: A comparison of the average monthly pH levels measured at the Sabie Falls gauging station during the 1970's compared to the 2000's. The 70's data includes monthly averages from October 1976 to December 1979, and the 2000's records from January 2000 to December 2009.

The pH values measured at the Klein Sabie gauging station, illustrated in Figure 5-7, demonstrate trends similar the results from the Sabie Falls station (Figure 5-5). At the Klein Sabie site, measured pH values increas e during low flow conditions and decrease during high flow conditions (Figure 5-7). Highest seasonal pH values were measured over August shifting towards July and more recently in August. The lowest pH values were recorded in March and February. Relatively low pH values were measured in the Klein Sabie River during the high flow season from March 1980 to February 1990, after which there is a steady increase in pH (Figure 5-7).

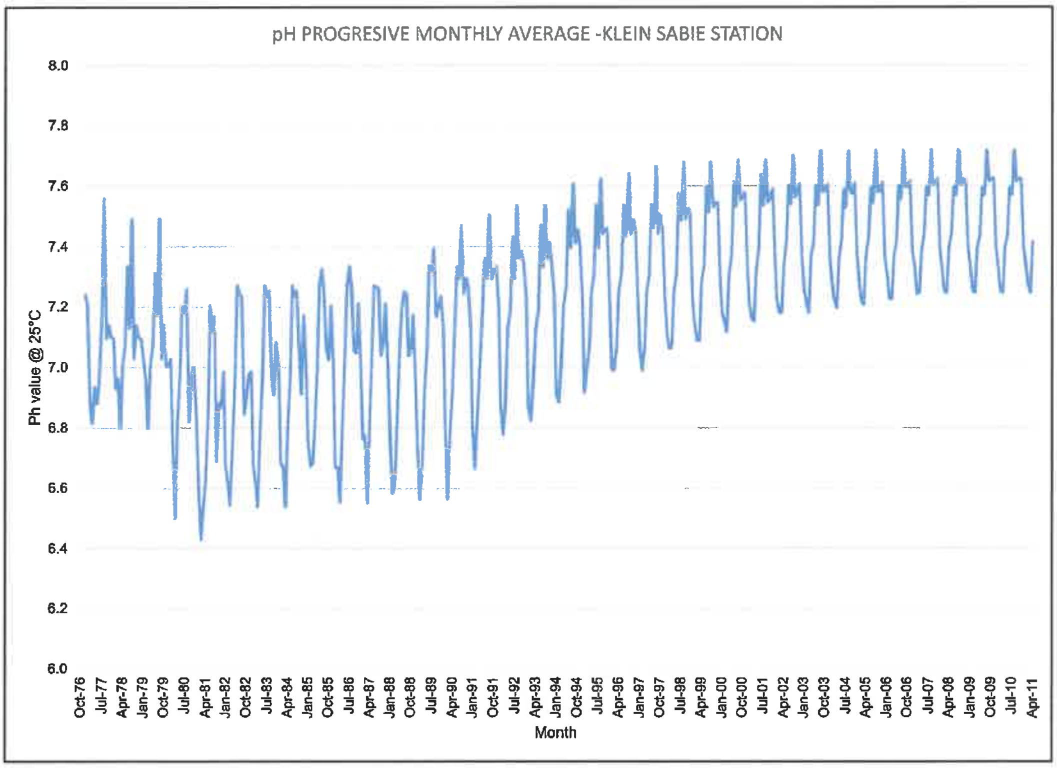


Figure 5-7: The progressive monthly average pH values measured at the Klein Sabie River Gauging station at Sabie Falls, from October 1976 to April 2011.

In Figure 5-8 that follows, the average pH values measured in the Klein Sabie River from October 1976 to December 1979 are considerably lower than those averages recorded from January 2000 to December 2009.

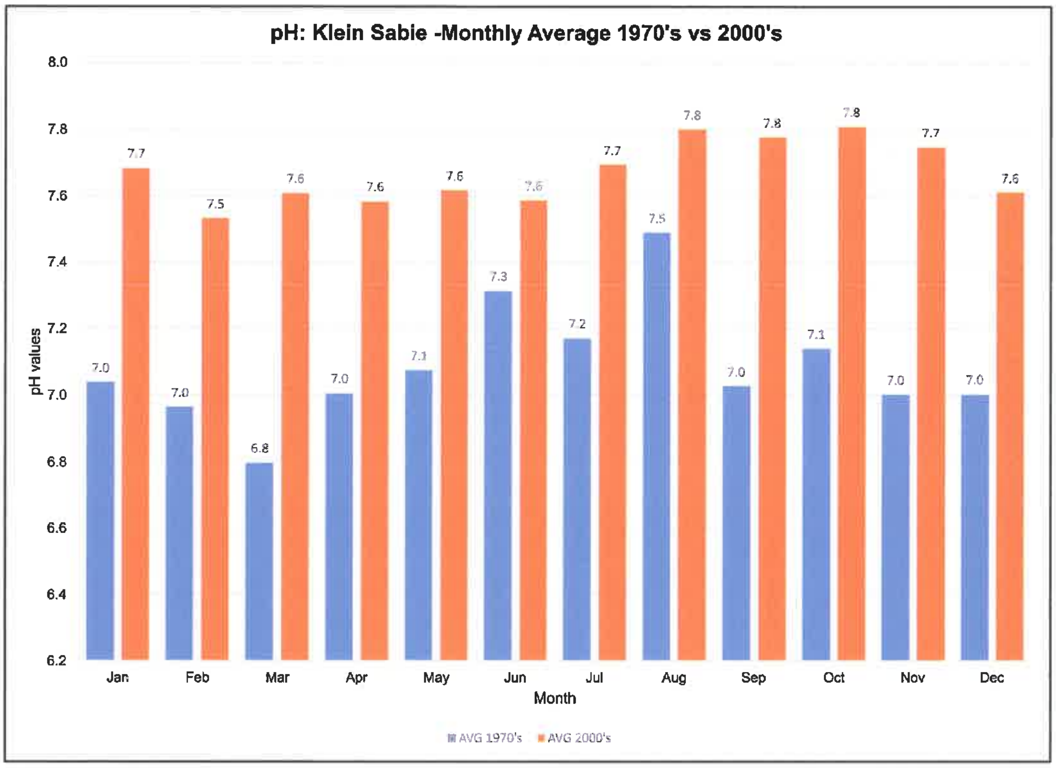


Figure 5-8: A comparison of the average monthly pH levels measured at the Klein Sabie gauging station during the 1970's compared to the 2000's. The 70's data includes monthly averages from October 1976 to December 1979, and the 2000's records from January 2000 to December 2009.

5.2.1.1 Sabie River

Results for the high and low flow monitoring in 2013 for sites along the Sabie River are presented. The pH measured during high flow conditions (February 2013) in the main Sabie River (Figure 5-9) were generally lower than measured during low flow conditions (September 2013). pH values were very similar in the upper reaches of the Sabie River, but the difference between high and low flow conditions were more pronounced lower down in the Sabie River (USM 22 – USM 1).

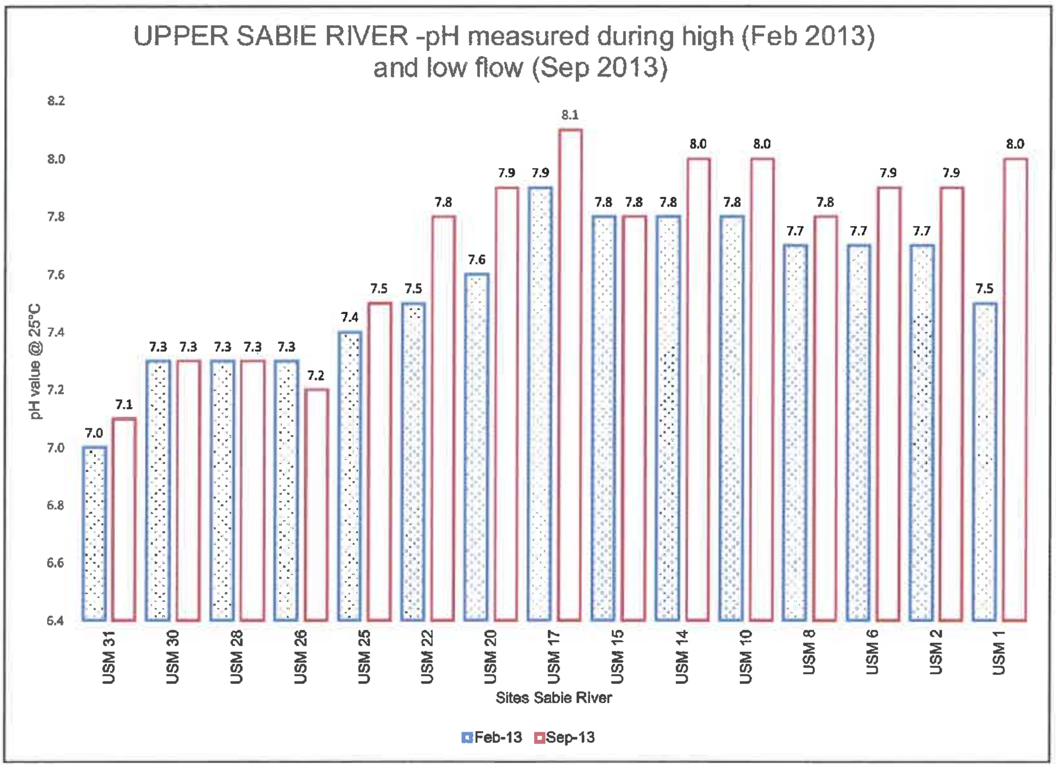


Figure 5-9: The pH values for sites located on the Sabie River. Site USM 31 is located in the headwaters and USM 1 at Aand-de-Vliet.

5.2.1.2 Sabie River Tributaries

On the tributaries (Figure 5-10), there is a general increase in pH values during low flow conditions compared to high flow. The Weber'sSpruit (USM 27), Lone Creek (USM 24), Bridal Veil (USM 21), Vertroostings (USM 19), Coopers Creek (USM 13), Malieveld (USM 12) and Mac-Mac (USM 3) tributaries stand out in terms of the increase in pH values during low flow conditions (compared to high flow).

At the site on the Sabaan River (USM 4), the situation is reversed, with higher pH values recorded during high flow than low flow.

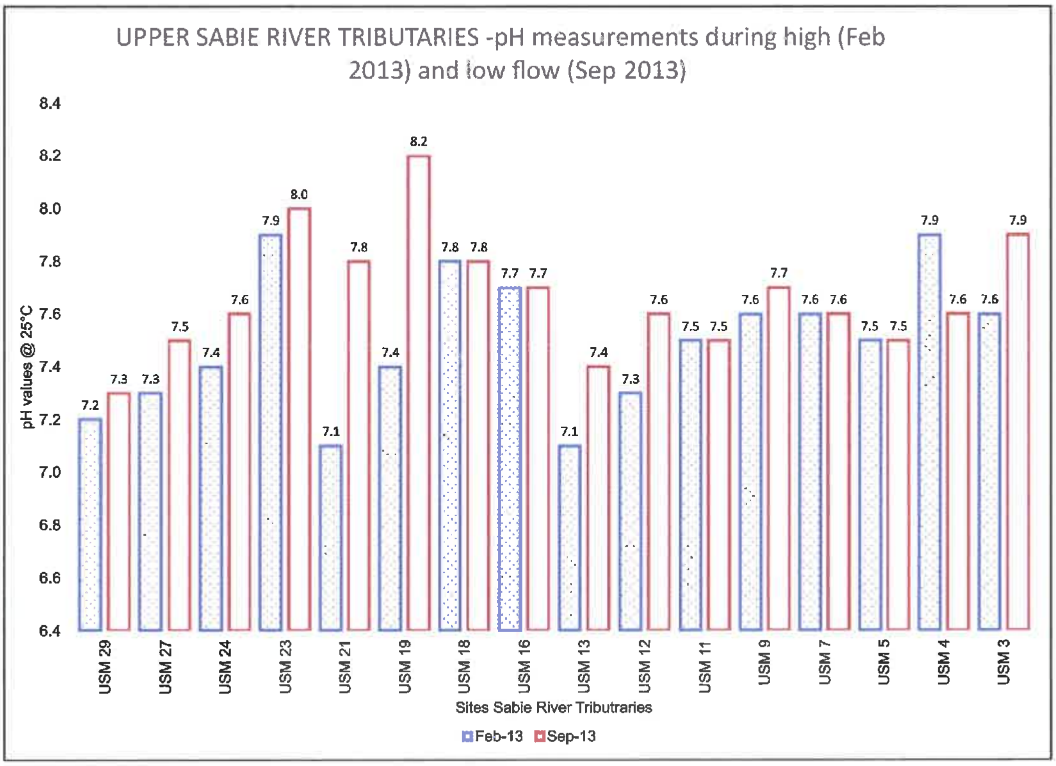


Figure 5-10: The pH values for sites located on the main tributaries of the Sabie River. Site USM 29 is located in the headwaters at Jantjiebos and USM 3 in the Mac-Mac River at Brandwag.

5.2.2 Electrical Conductivity

Results are graphically illustrated for sites located in the main Sabie River from Headwaters (USM 31) to Aand-de-Vliet (USM 1) and for tributaries of the Sabie River from headwaters to the Mac-Mac confluence.

Based on historical (1976-2010) electrical conductivity values measu red at the Sabie Falls Gauging station, electrical conductivity increase during low flow conditions and decrease during high flow conditions (Figure 5-11). Highest seasonal EC values were initially measured over July, August and October. The lowest EC values fell between the months of December, January, and February. The historical results indicate a steady increase in EC since the first measurements were made in 1976.

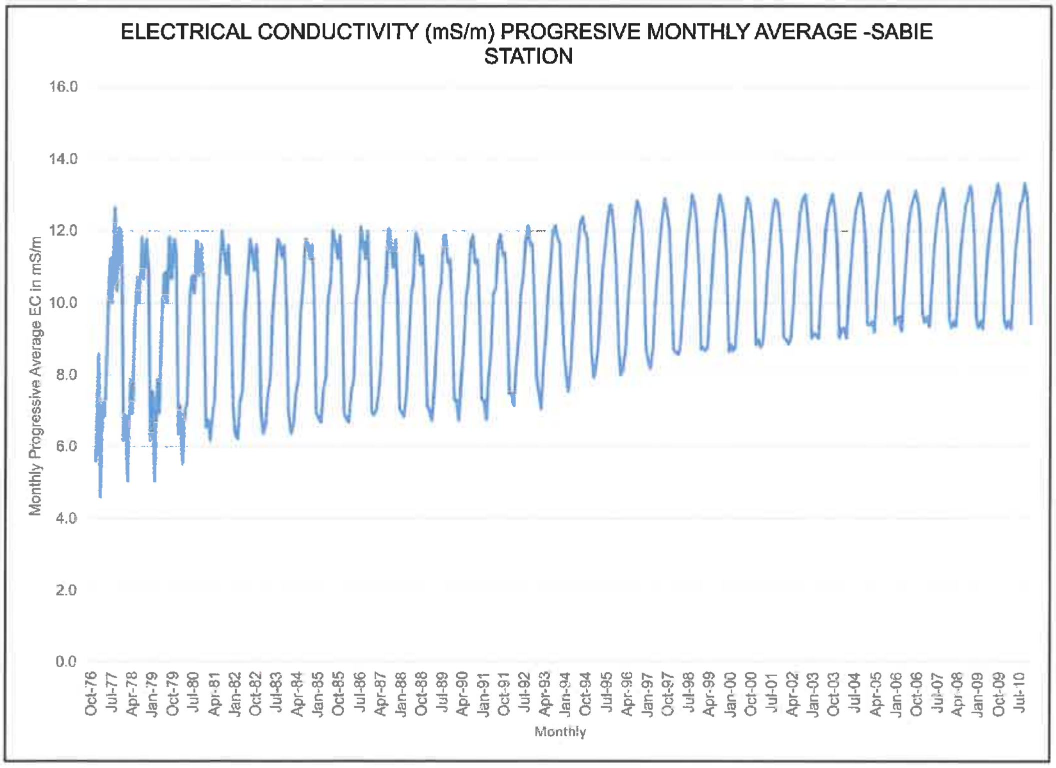


Figure 5-11: The progressive monthly average electrical conductivity values measured at the Sabie Falls Gauging station from October 1976 to December 2010.

The increase in electrical conductivity levels in the Sabie River is further illustrated when comparing the average EC measured in the Sabie River (at Sabie Falls) from October 1976 to December 1979 to those averages recorded from January 2000 to December 2009 (Figure 5-12).

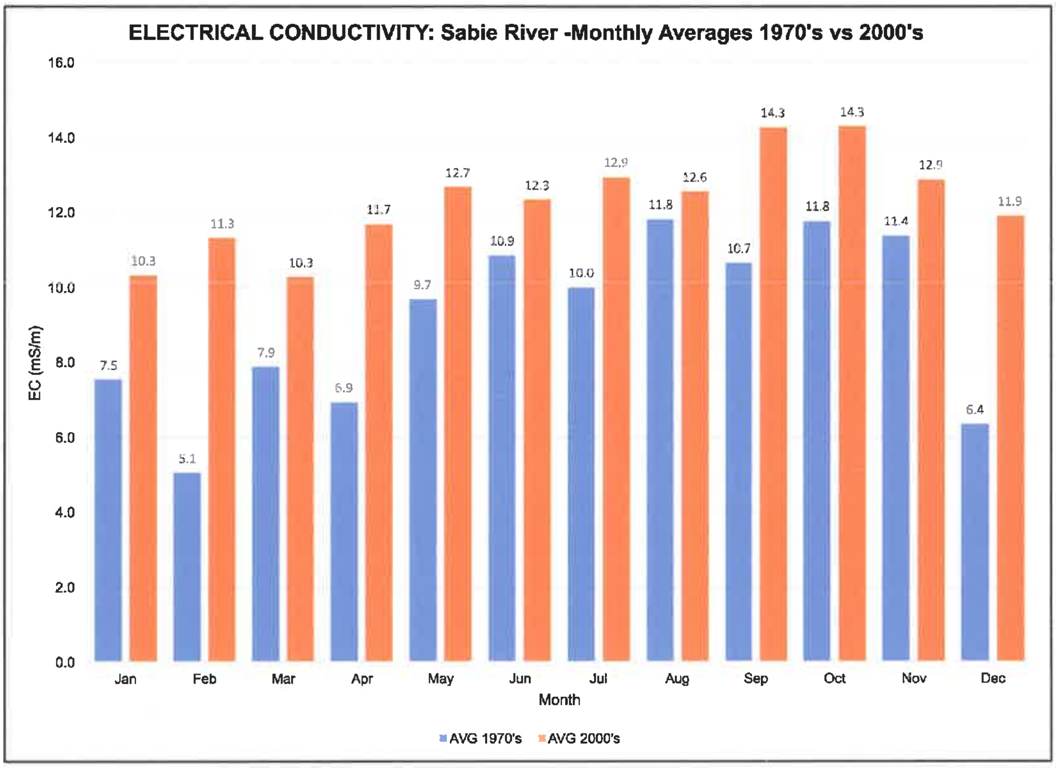


Figure 5-12: A comparison of the average monthly electrical conductivity levels measured at the Sabie Falls gauging station during the 1970's compared to the 2000's. The 70's data includes monthly averages from October 1976 to December 1979, and the 2000's records from January 2000 to December 2009.

In the Klein Sabie River, electrical conductivity is initially low (1970's) but rapidly increased. Electrical conductivity increase in the Klein Sa bie River during low flow conditions and decrease during high flow conditions (Figure 5-13). Highest seasonal EC values were measured over June, September and December. The lowest EC values fell between the months of March, April and October. The historical results indicate a steady increase in EC up to 1999, after which it stabilises.

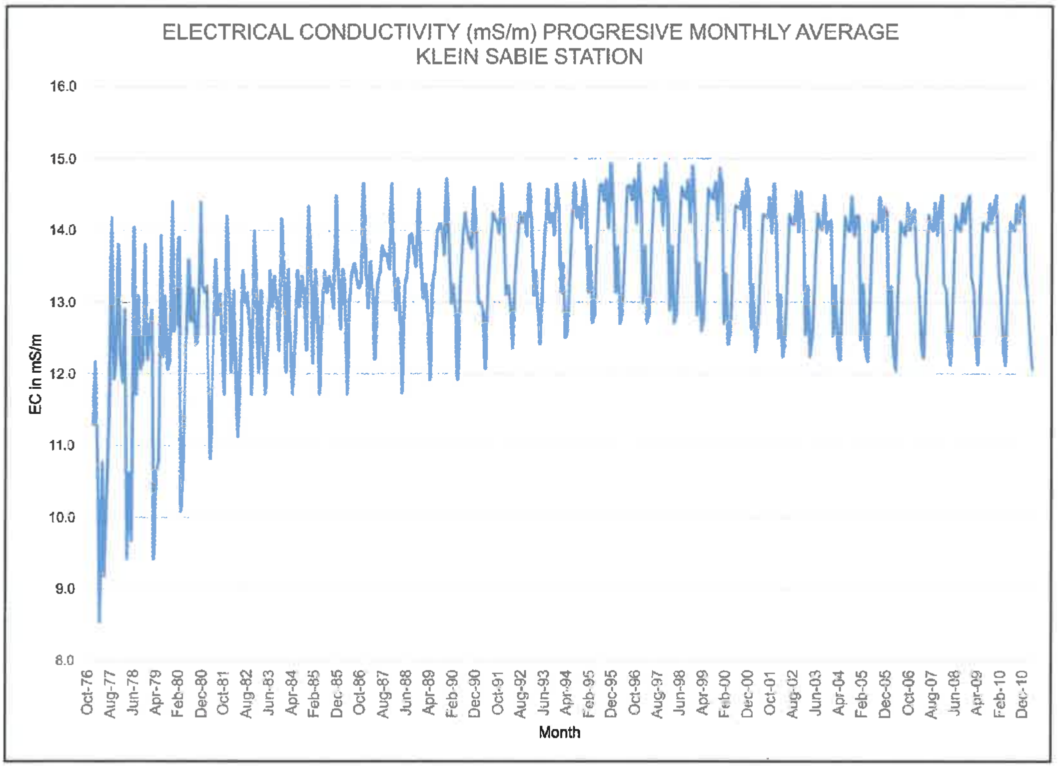


Figure 5-13: The progressive monthly average electrical conductivity values measured at the Klein Sabie Gauging station at Sabie Falls, from October 1976 to April 2011.

5.1.2.1 Sabie River

Electrical conductivity is low and fairly similar between high and low flow conditions for sites on the Sabie River from the Headwaters site (USM 31) to Sabieshoek (USM 25), steadily increasing as one moves downstream along the river (Figure 5-14). Electrical conductivity increases in the Sabie River between high and low flow were pronounced at the Above York Saw-mill (USM 22), Below York Saw-mill (USM 20), Sabie Sewage Farm (USM 17), Rietfontein Mine (USM 14), DR de Wet (USM 10), Brandwag (USM 2) and Aand-de-Vliet (USM 1) sites.

Electrical conductivity was higher during high flow than low flow at the sites Above Mine (USM 15) and Lunsklip (USM 6) in the Sabie River.

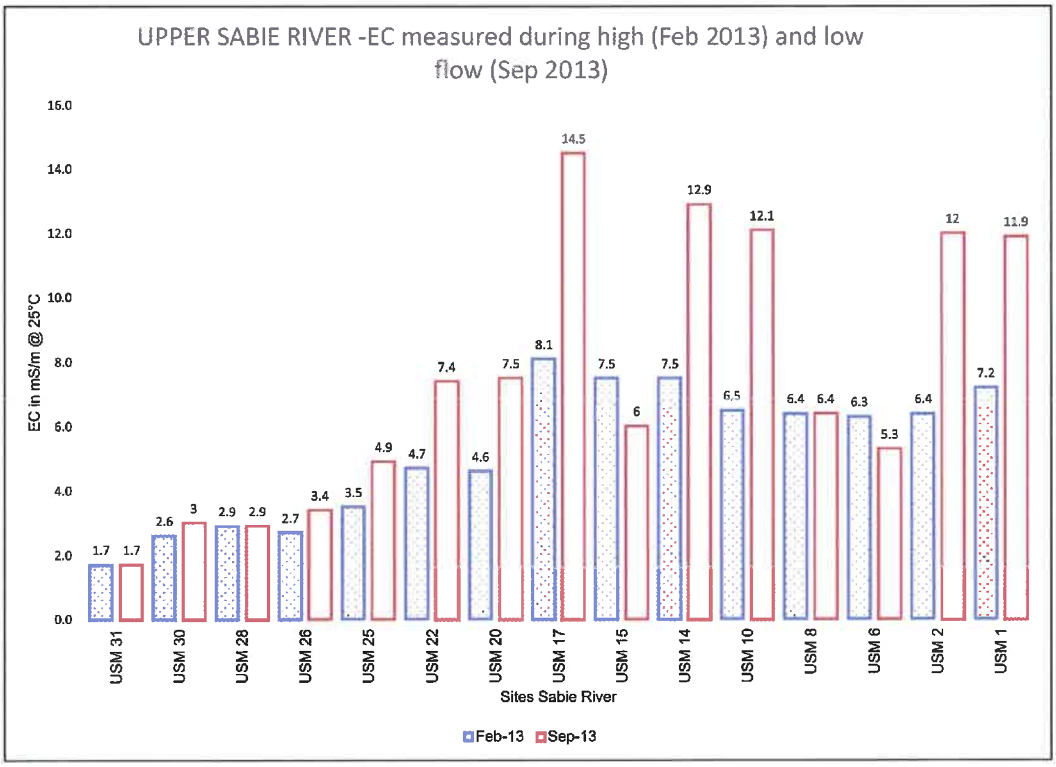


Figure 5-14: Electrical conductivity values for sites located on the Sabie River. Site USM 31 is located in the headwaters and USM 1 at Aand-de-Vliet.

5.2.2.2 Sabie River Tributaries

Relatively high electrical conductivity (Figure 5-15) was measured in the Manyeleti (USM 23), Vertroostings (USM 19), Klein Sabie (USM 18), Spitskopspruit (USM 16), Coopers Creek (USM 13), KaMahukwane (USM 7) and Sabaan (USM 4) Rivers. Relatively low conductivity was meas ured at the Jantjiesbos (USM 29), Weber's Spruit (USM 27), Malieveldspruit (USM 12), DR de Wet (USM 11) and Goudstroom (USM 9) sites.

In most of the tributaries, electrical conductivity was higher during low flow conditions than during high flow. Sites where there was a considerable increase in EC from low to high flow conditions included Lone Creek (USM 24), Manyeleti (USM 23), Bridal Veil (USM 21), Vertroostings (USM 19), Klein Sabie (USM 18), Spitskopspruit (USM 16), Coopers Creek (USM 13), KaMahukwane (USM 7), Sabaan (USM 4) and Mac-Mac (USM 3).

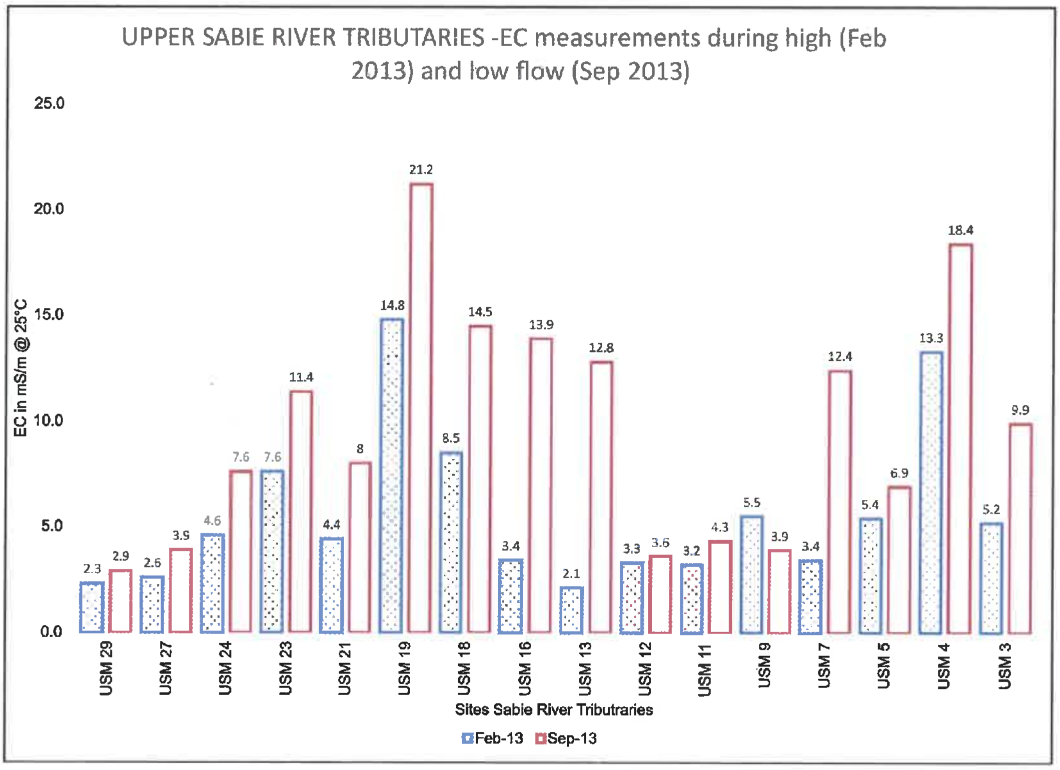


Figure 5-15: Electrical Conductivity values for sites located on the main tributaries of the Sabie River. Site USM 29 is located in the headwaters at Jantjiebos and USM 3 in the Mac-Mac River at Brandwag.

5.2.3 Chloride (Cl)

Results are graphically illustrated for sites located in the main Sabie River from Headwaters (USM 31) to Aand-de-Vliet (USM 1), and for tributaries of the Sabie River from headwaters to the Mac-Mac confluence.

Historical results indicate a considerable increase in chloride levels measured in the Sabie River at the Sabie Falls since October 1976 (Figure 5-16). This increase is also illustrated in Figure 5-17, when comparing results in the Sabie River (at Sabie Falls) from October 1976 to December 1979 to those averages recorded from January 2000 to December 2009.

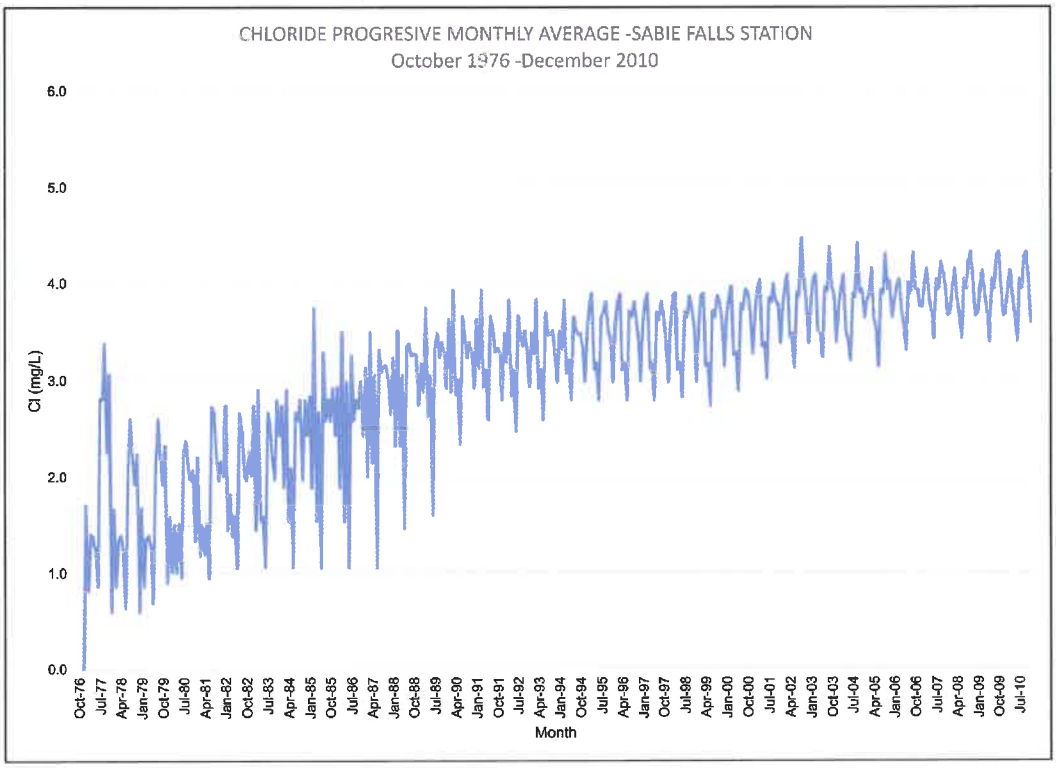


Figure 5-16: The progressive monthly average Chloride (Cl) values measured at the Sabie Falls Gauging station from October 1976 to December 2010.

This increase is also illustrated in Figure 5-17.

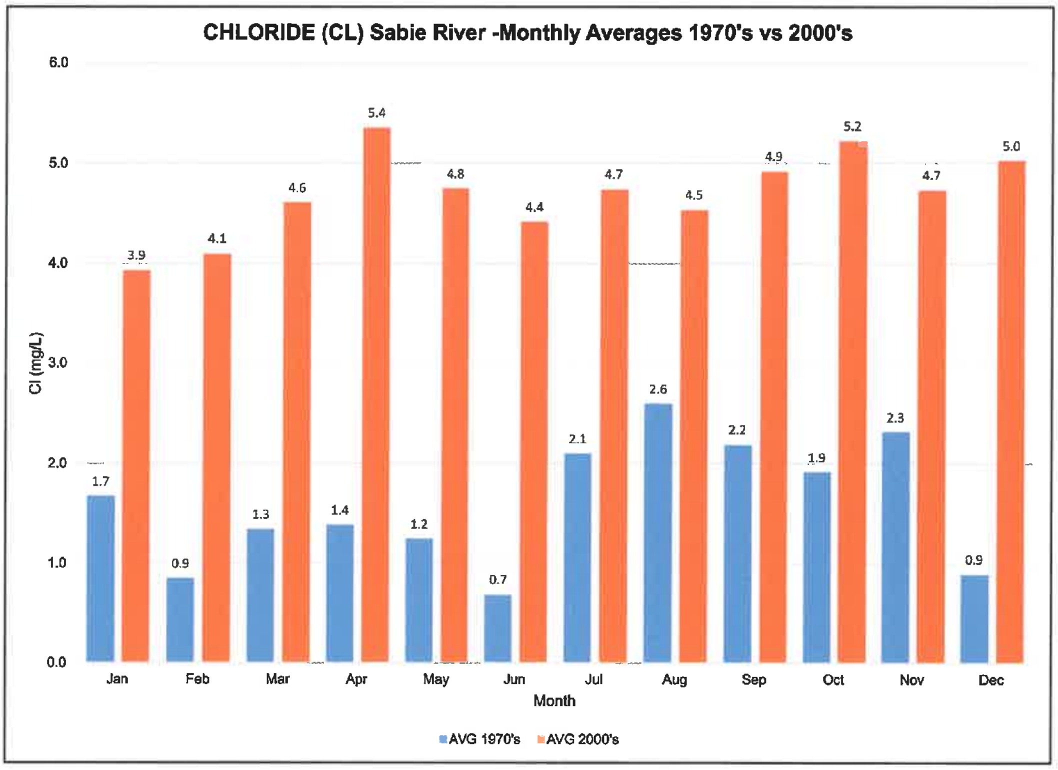


Figure 5-17: A comparison of the average monthly chloride levels measured at the Sabie Falls gauging station during the 1970's compared to the 2000's. The 70's data includes monthly averages from October 1976 to December 1979, and the 2000's records from January 2000 to December 2009

The historical results of chloride measurements at the Klein Sabie sampling point, indicates a considerable increase in chloride levels from 1976 to July 1990, where it peaks up to July 1993 and then steadily decrease. Overall, average values in 2011 are considerably higher than those recorded in the 1970's.

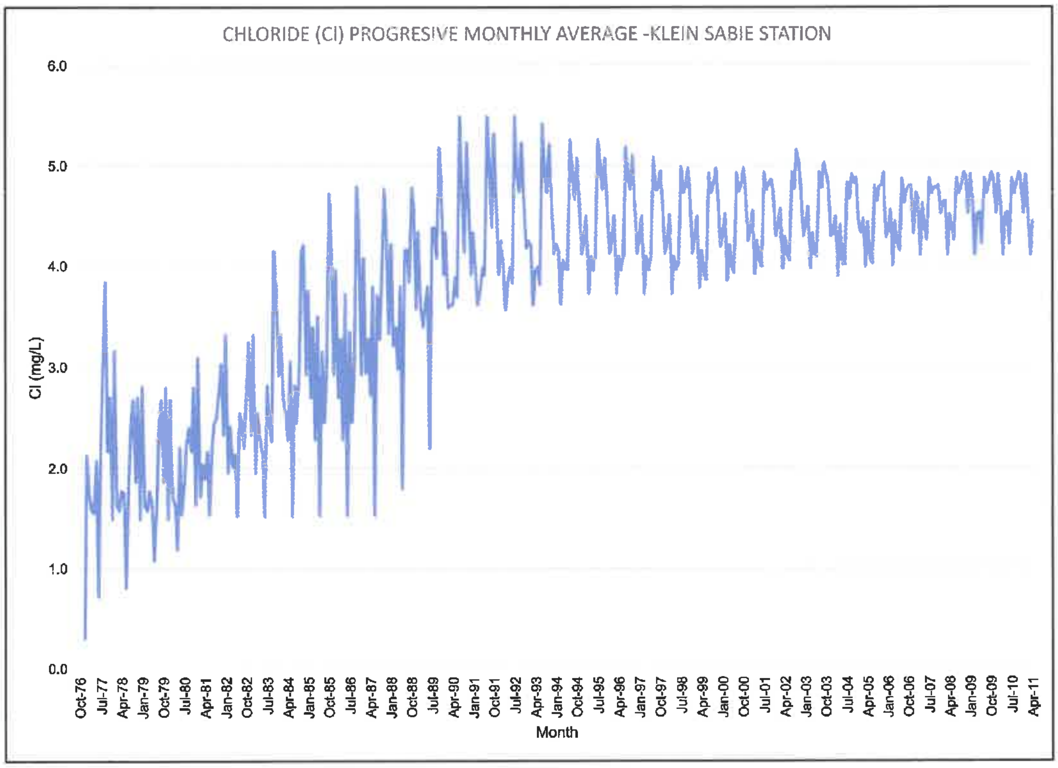


Figure 5-18: The progressive monthly average chloride values measured at the Klein Sabie River Gauging station at Sabie Falls, from October 1976 to April 2011.

The increase in chloride values in the Klein Sabie River form October 1976 to April 2011 is clearly illustrated in Figure 5-19.

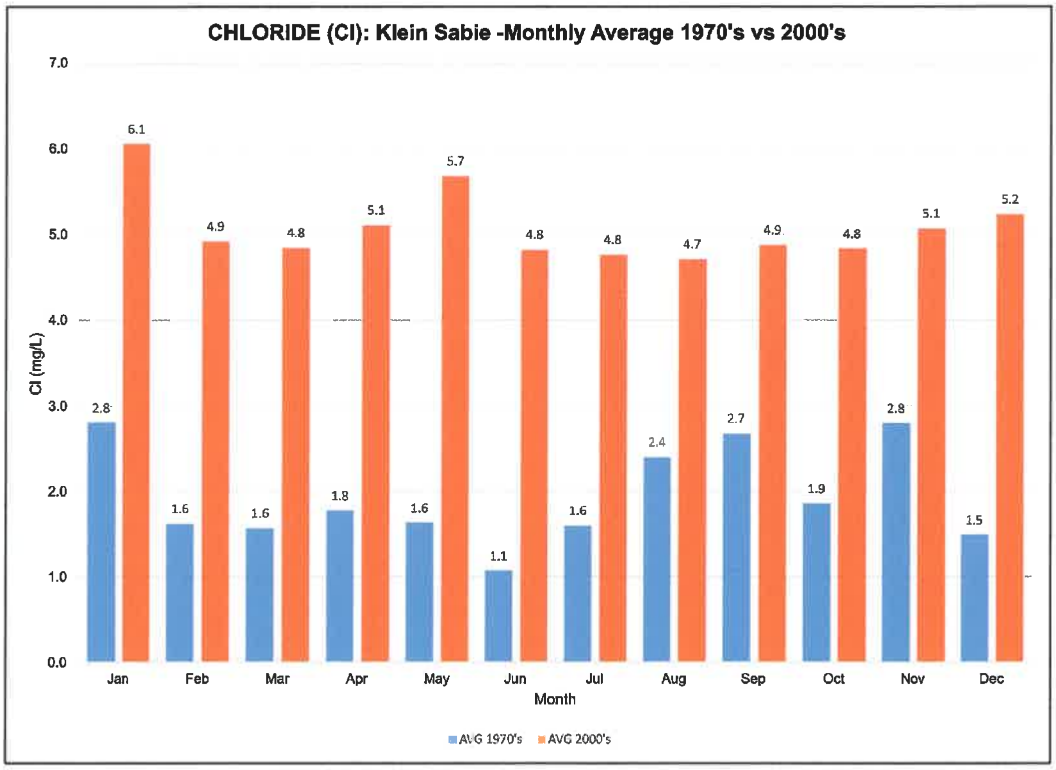


Figure 5-19: A comparison of the average monthly chloride levels measured at the Klein Sabie gauging station during the 1970's compared to the 2000's. The 70's data includes monthly averages from October 1976 to December 1979, and the 2000's records from January 2000 to December 2009.

5.2.3.1 Sabie River

Only detectable chloride levels 5 mg/ℓ are recorded by the laboratory. There were only two sites, namely the Below Horseshoe Falls (USM 26) and Rietfontein Mine (USM 14) sites where such levels were recorded during high flow conditions (February 2013) as reflected in the graph below.

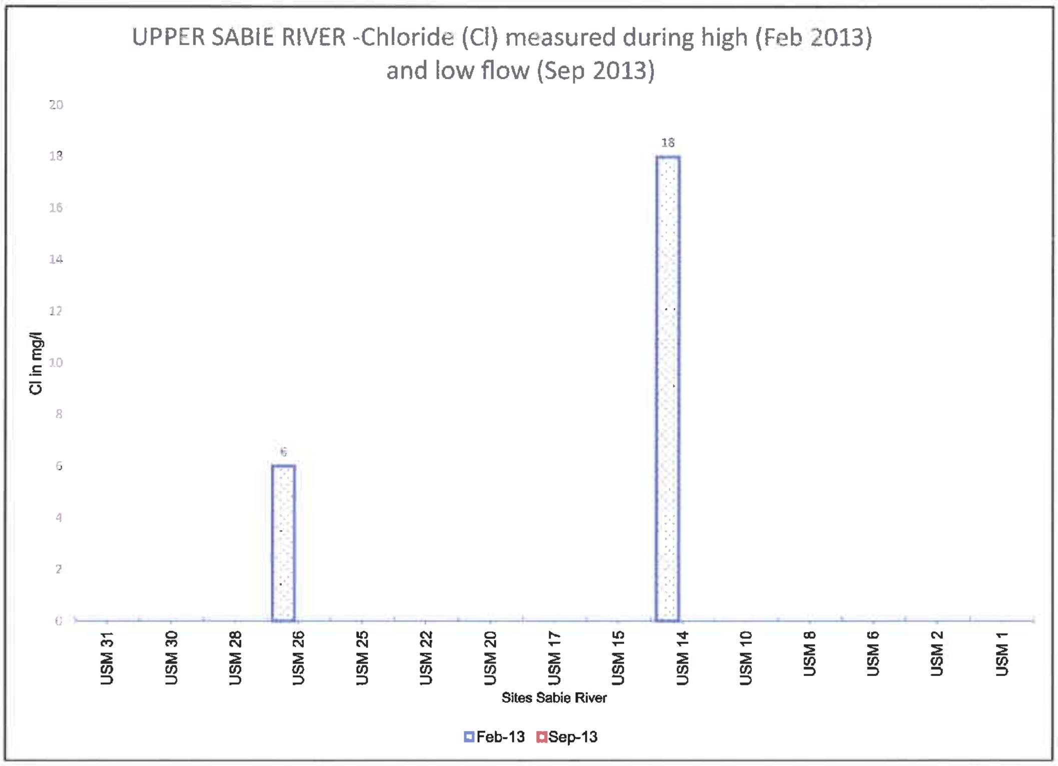


Figure 5-20: Chloride (Cl) values for sites located on the Sabie River. Site USM 31 is located in the headwaters and USM 1 at Aand-de-Vliet.

5.2.3.2 Sabie River Tributaries

Detectable chloride levels 5 mg/ℓ were measured during high flow conditions in the DR de Wet stream (USM 11) and Buffelspruit (USM 5) tributaries of the Sabie River, and in the Goudstroom (USM 9), Buffelspruit (USM 5) and Sabaan (USM 4) rivers during low flow conditions.

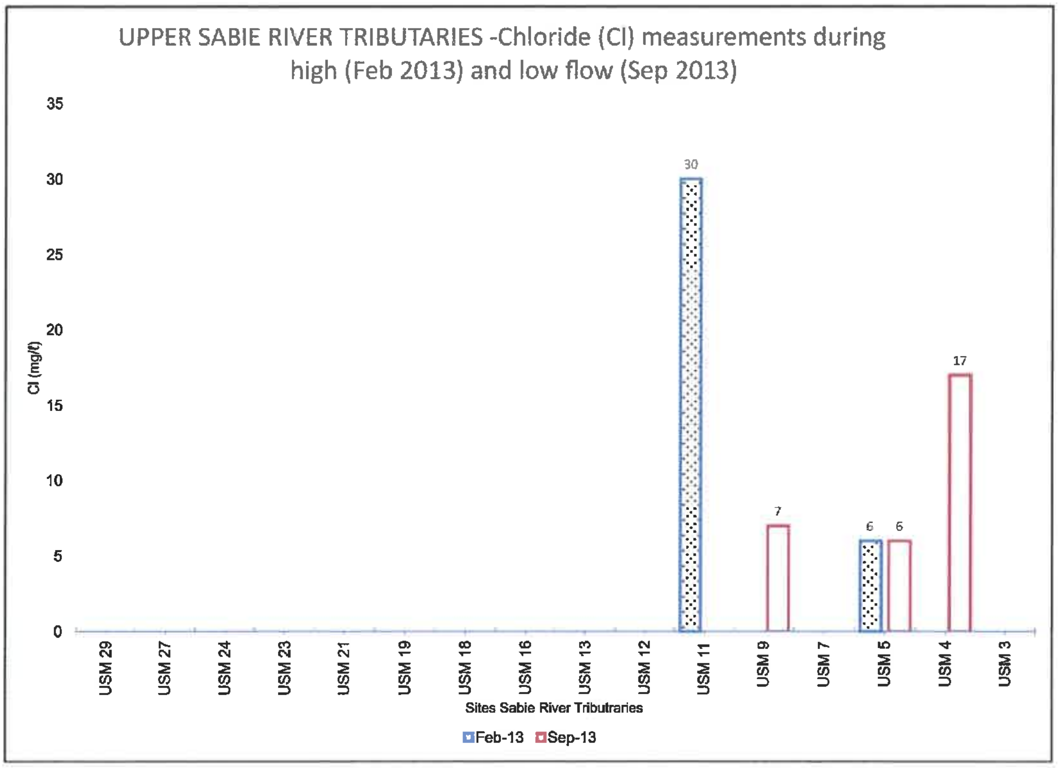


Figure 5-21: Chloride (Cl) values for sites located on the main tributaries of the Sabie River. Site USM 29 is located in the headwaters at Jantjiebos and USM 3 in the Mac-Mac River at Brandwag.

5.2.4 Sulphate (SO_4)

The current water samples were analysed for sulphate (SO_4), measured in mg/ℓ. Historical SO_4 results dating back to October 1976 suggests a subtle increase from the 1990's peaking in the 2000's followed by a slight decrease (Figure 5-22). There are seasonal variations, but the highest values were initially measured over February-March, and in later years September.

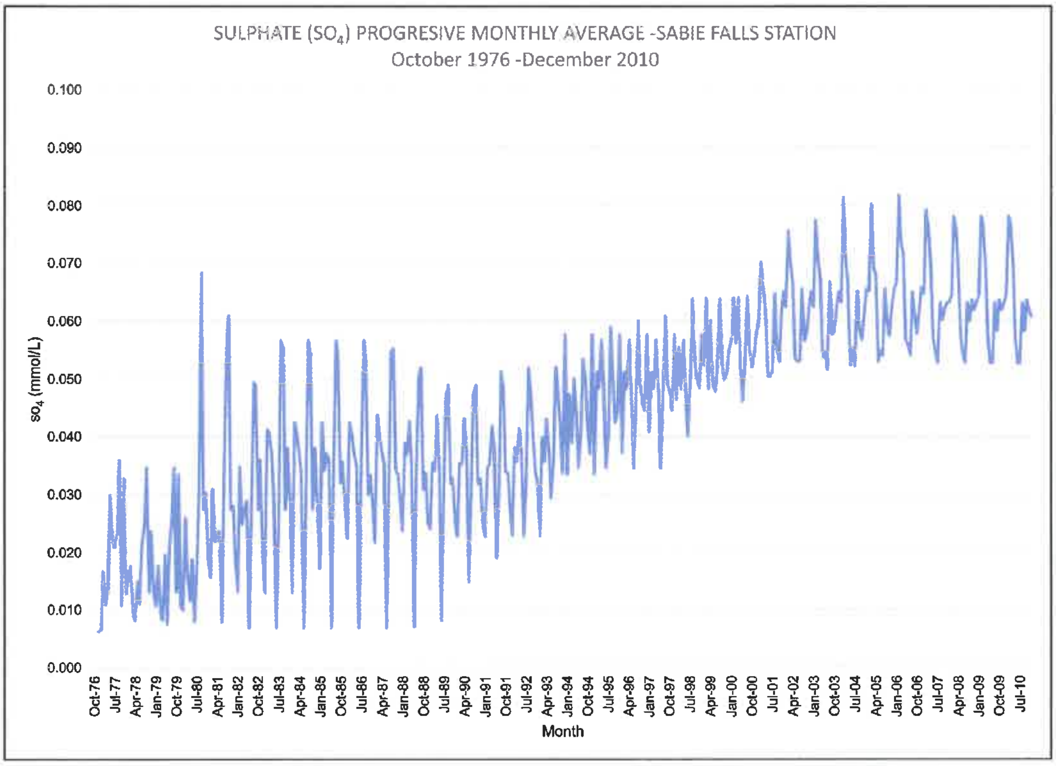


Figure 5-22: The progressive monthly average Sulphate (SO_4) values measured at the Sabie Falls Gauging station from October 1976 to December 2010.

At the Klein Sabie site, historical results indicate steady SO_4 levels during low flow conditions, but a steady decrease in peak values since February 1981 (Figure 5-23).

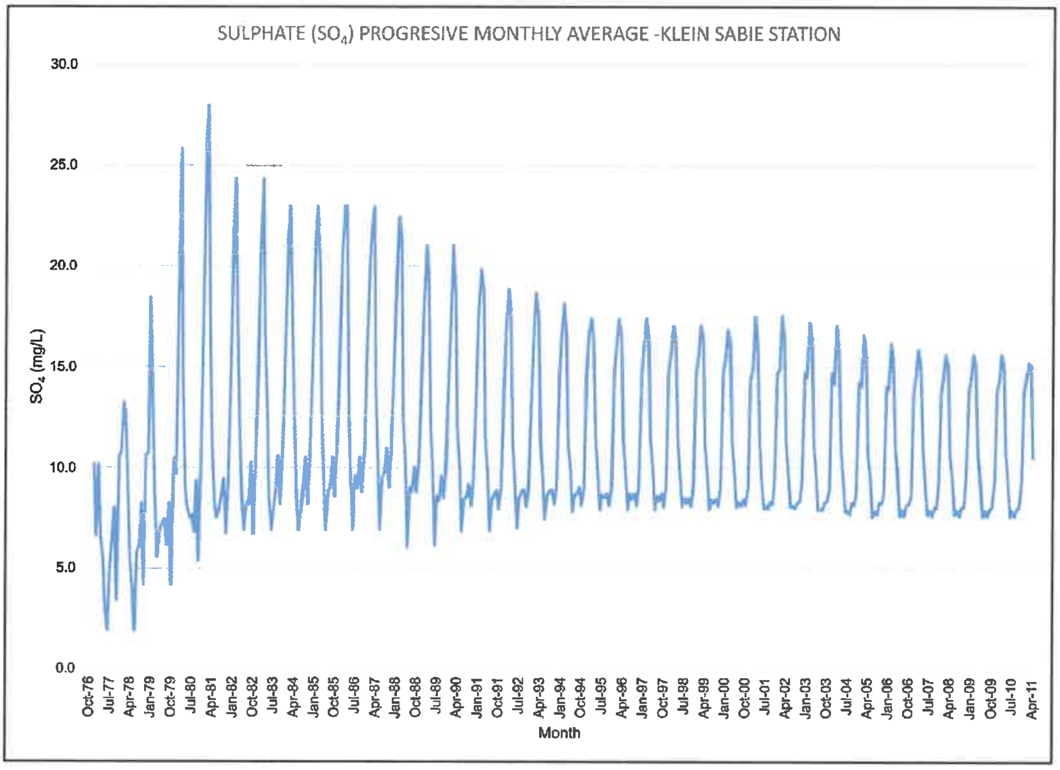


Figure 5-23: The progressive monthly average sulphate values measured at the Klein Sabie River Gauging station at Sabie Falls, from October 1976 to April 2011.

5.2.4.1 Sabie River

Detectable sulphate levels 5 mg/ℓ was only recorded in samples collected in the Sabie River during low flow conditions (September 2013) at the Sabieshoek (USM 25), and then from the Sabie Sewage Farm (USM 17) all the way down to the Aand-de-Vliet site (USM 1).

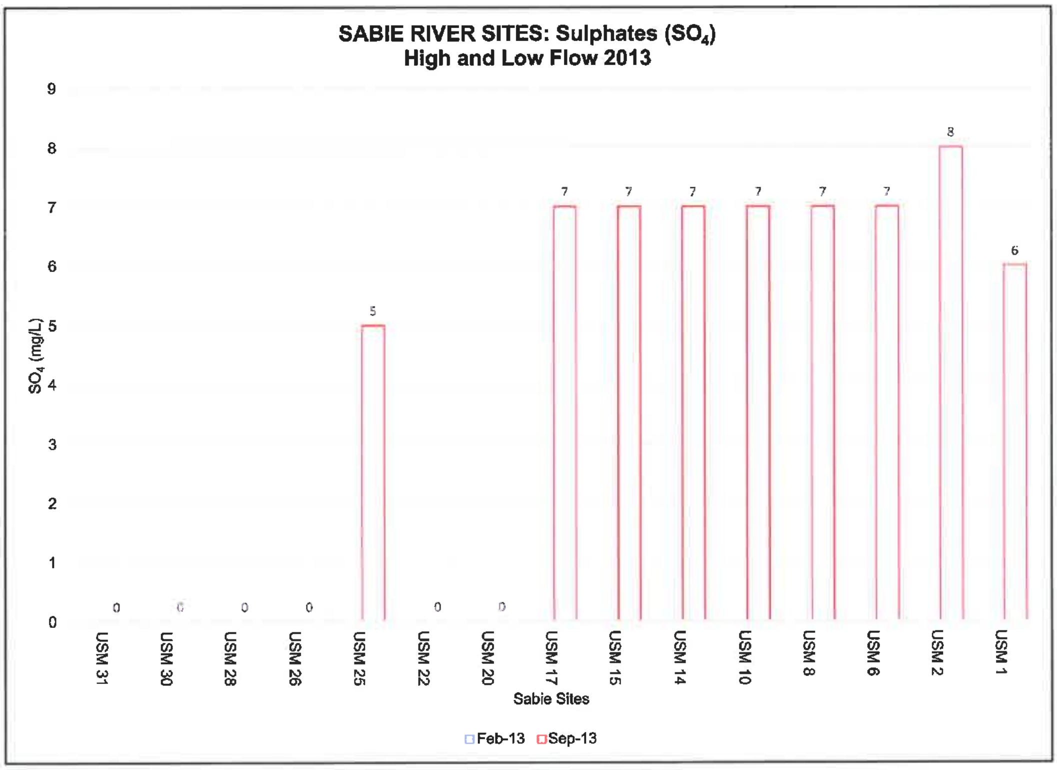


Figure 5-24: Sulphate (SO_4) values for sites located on the Sabie River. Site USM 31 is located in the headwaters and USM 1 at Aand-de-Vliet.

5.2.4.2 Sabie River Tributaries

On the tributaries detectable sulphate levels 5 mg/ℓ were only measured during high flow conditions in the Klein Sabie (USM 18) but on three tributaries during low flow conditions. These were Vertroostings (USM 19), Klein Sabie and Sabaan (USM 4).

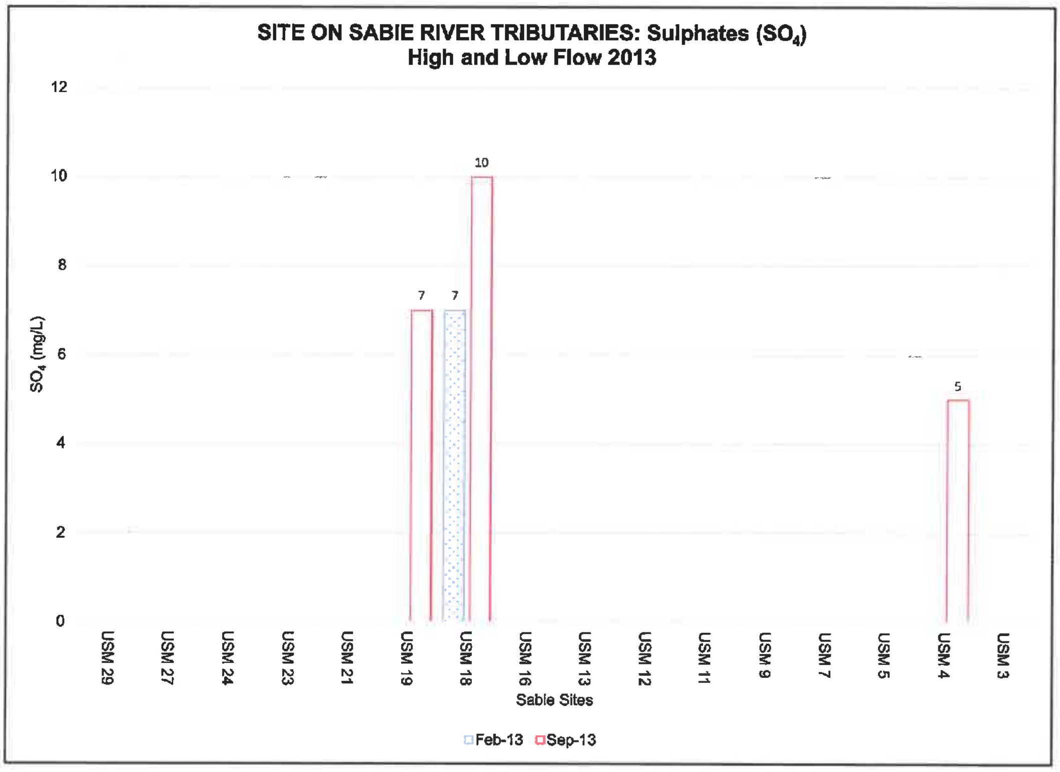


Figure 5-25: Sulphate (SO_4) values for sites located on the main tributaries of the Sabie River. Site USM 29 is located in the headwaters at Jantjiebos and USM 3 in the Mac-Mac River at Brandwag.

5.2.5 Nitrate (NO_3)

Historical results suggests a steady increase in nitrate levels since the first records were collected in October 1976 (Figure 5-26). The highest values are measured in August (low flow) and the lowest between December and January (high flow).

Results for the 2013 monitoring are graphically illustrated for sites located in the main Sabie River from Headwaters (USM 31) to Aand-de-Vliet (USM 1), and for tributaries of the Sabie River from headwaters to the Mac-Mac confluence.

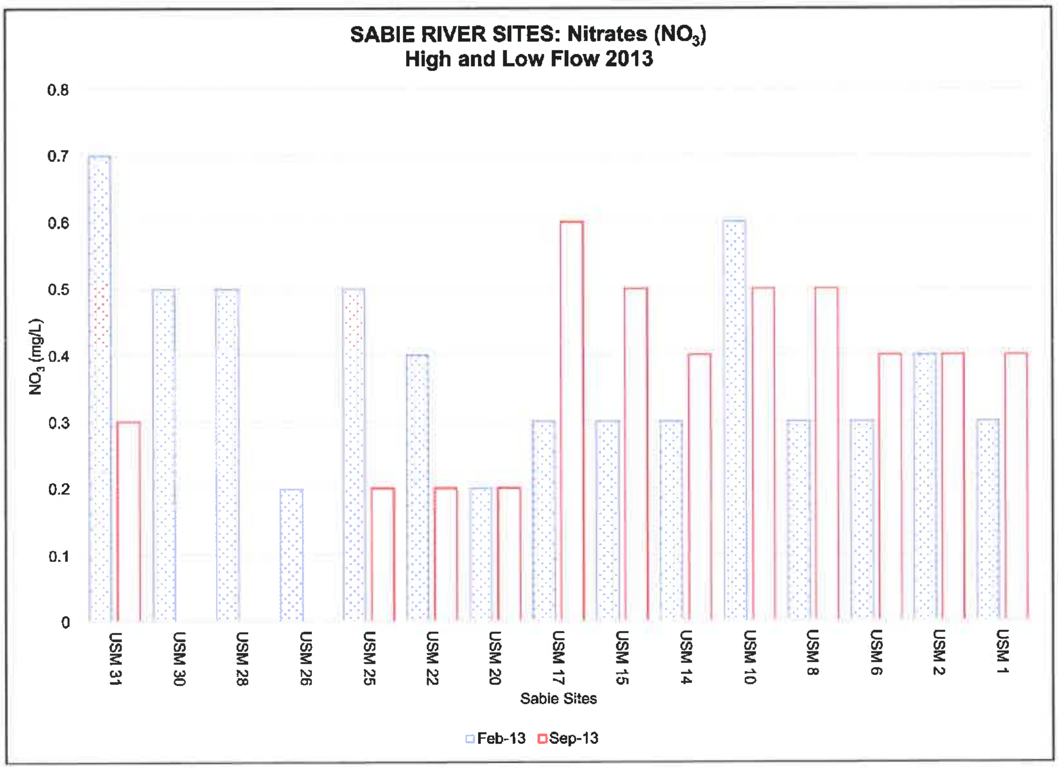


Figure 5-27: Nitrate (NO $_3$) values for sites located on the Sabie River. Site USM 31 is located in the headwaters and USM 1 at Aand-de-Vliet.

5.2.5.2 Sabie River Tributaries

On the tributaries (Figure 5-28), detectable nitrate levels 0.2 mg/ℓ were only measured on all the tributaries sampled during high flow with the exception of DR de Wet (USM 11), Goudstroom (USM 9) and KaMahukwane (USM 7). The highest values during high flow was measured on the Cooper s Creek (USM 13) and Mac-Mac (USM 3) sites.

During low flow, no detectable nitrate levels were measured at the Jantjiesbos (USM 29), Weber's Spruit (USM 27), DR de Wet (USM 11), Goudstroom (USM 9) and KaMahukwane (USM 7) sites. The highest nitrate levels during high flow was measured on the Klein Sabie River (USM 18).

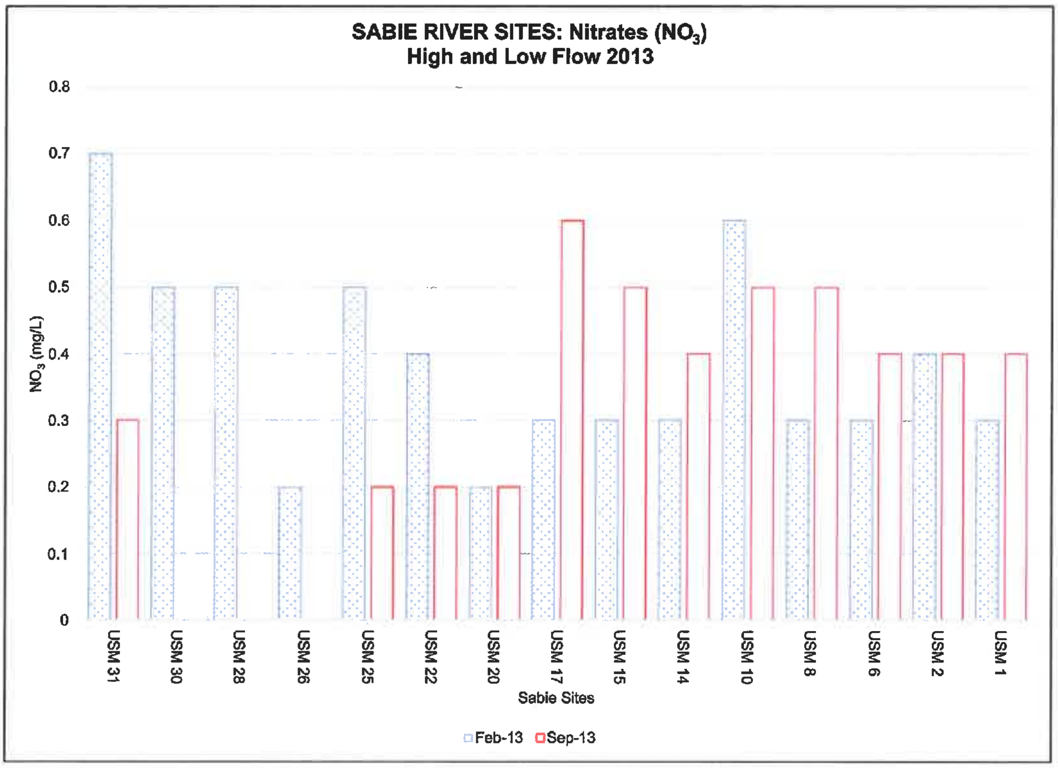


Figure 5-27: Nitrate (NO $_3$) values for sites located on the Sabie River. Site USM 31 is located in the headwaters and USM 1 at Aand-de-Vliet.

5.2.5.2 Sabie River Tributaries

On the tributaries (Figure 5-28), detectable nitrate levels 0.2 mg/ℓ were only measured on all the tributaries sampled during high flow with the exception of DR de Wet (USM 11), Goudstroom (USM 9) and KaMahukwane (USM 7). The highest values during high flow was measured on the Cooper s Creek (USM 13) and Mac-Mac (USM 3) sites.

During low flow, no detectable nitrate levels were measured at the Jantjiesbos (USM 29), Weber's Spruit (USM 27), DR de Wet (USM 11), Goudstroom (USM 9) and KaMahukwane (USM 7) sites. The highest nitrate levels during high flow was measured on the Klein Sabie River (USM 18).

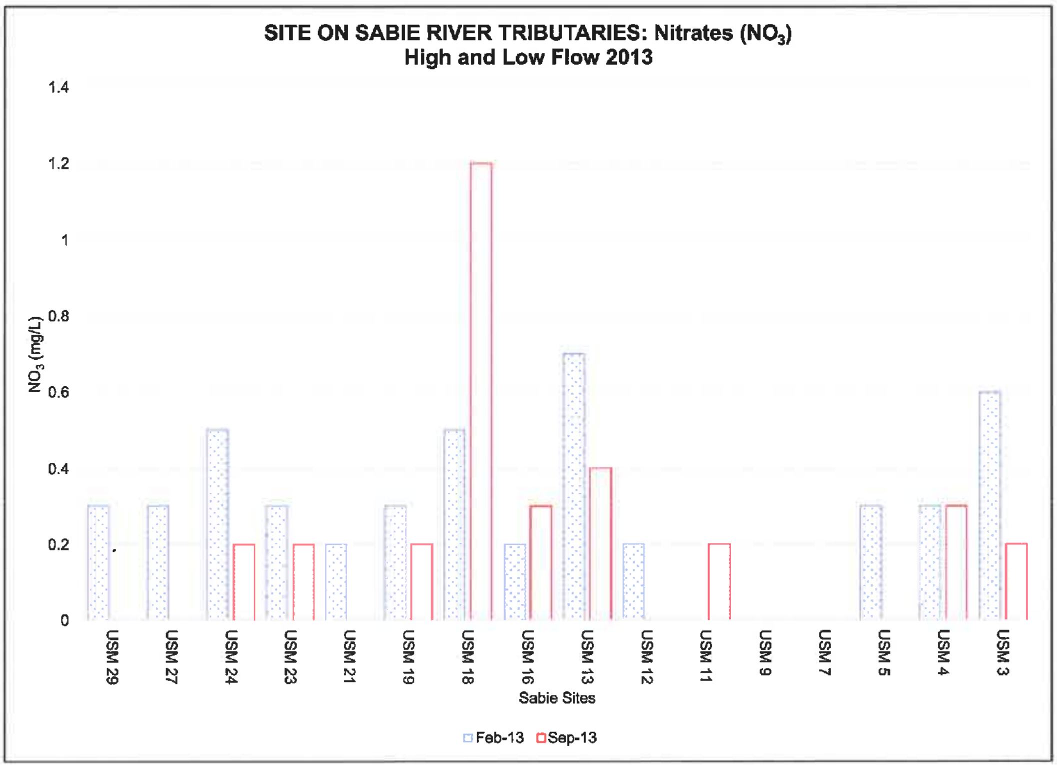


Figure 5-28: Nitrate (NO_3) values for sites located on the main tributaries of the Sabie River. Site USM 29 is located in the headwaters at Jantjiebos and USM 3 in the Mac-Mac River at Brandwag.

5.2.6 Nitrite (NO_2)

Detection limit from the laboratory results was 0.1 mg/ℓ. The only site where nitrites above this limit was measured (0.2 mg/L) was below the Sabie Sewage Farm (USM 17) during the low flow sampling event.

5.2.7 Ortho Phosphate (P)

Detection limit from the laboratory results was 0.1 mg/ℓ for the high flow samples and 0.05 mg/ℓ for the low flow samples. None of the sites sampled had values above these limits during both the high and low flow sampling periods.

5.2.8 Chemical Oxygen Demand (COD)

The detection limit for COD was 10 mg/ℓ. COD levels of 28g/L and 20 mg/ℓ was measured during high flow conditions (February 2013) at the Buffelspruit (USM 5) and Mac-Mac (USM 3) sites. No detectable COD levels were measured at any of the other sites during both the high and low flow sampling events.

5.2.9 Escherichia coli (E coli)

Results for the 2013 monitoring are graphically illustrated for sites located in the main Sabie River from Headwaters (USM 31) to Aand-de-Vliet (USM 1), and for tributaries of the Sabie River from headwaters to the Mac-Mac confluence.

E coli counts increased considerably during the low flow season compared to counts during high flows.

5.2.9.1 Sabie River

Low E coli plate counts (Feb 2013 = 0 counts/100 mℓ) were recorded at the Sabie Headwaters sites (USM 31) in the Sabie River during both the high and low flow sampling event. No E coli was detected during the high flow sampling event at the Sabie Headwaters, Ceylon (USM 30), Sabieshoek (USM 25), Below York Sawmill (USM 20), Sabie Sewage Farm (USM 17) and Lunsklip (USM 6) sites. Plate counts of >10 per 100 mℓ during high flow was only recorded at the Brandwag (USM 2) site.

E coli levels were considerably higher during the low flow sampling event (September 2013). Plate counts at 13 of the 15 sites sampled on the Sabie River (87 %) during low flow conditions were >10 counts/100 mℓ, and were over 100 at five of the 15 sites (33%). Three sites, Above Rietfontein Mine (USM 14), DR de Wet-Sabie (USM 10) and Frankfort Bridge (USM 8), had plate counts of >1000. E. coli levels increase rapidly about 1.5 km downstream from the Sabie Sewage Farm, slowly decreasing further towards Aand-de-Vliet (USM 1).

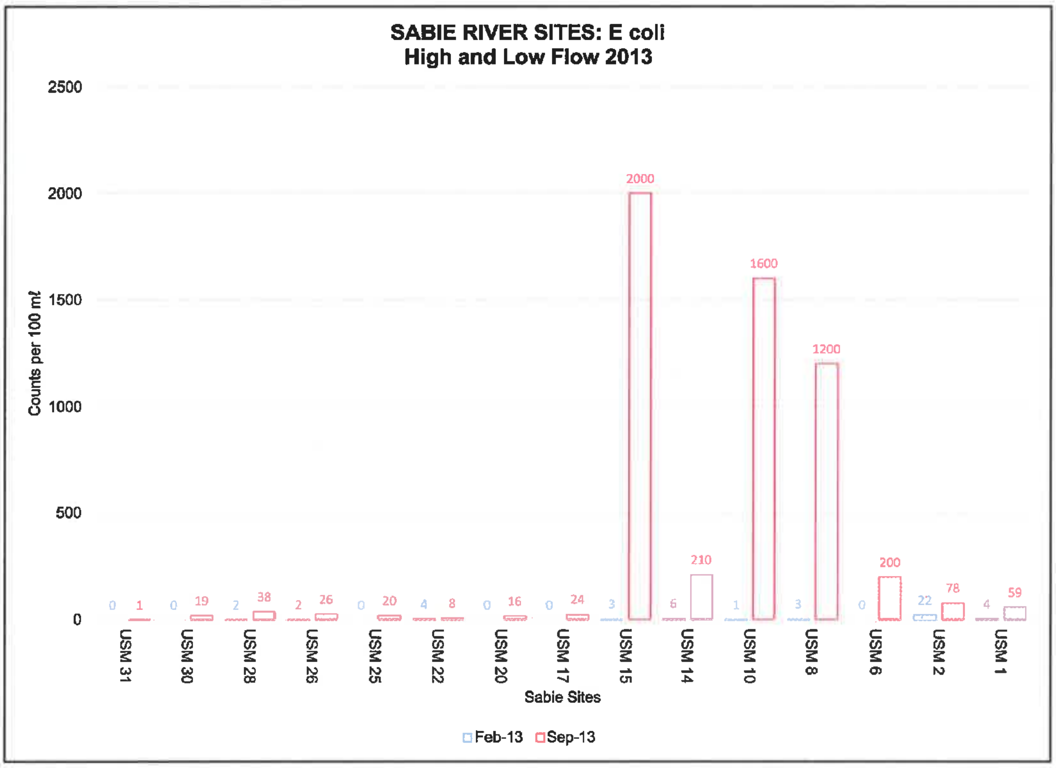


Figure 5-29: E coli values for sites located on the Sabie River. Site USM 31 is located in the headwaters and USM 1 at Aand-de-Vliet.

5.2.9.2 Sabie River Tributaries

During the high flow season, no E coli was recorded in samples collected in the Bridal Veil and Coopers Creek. Counts <10/100 mℓ during both the high and low flow seasons were recorded in the Jantjiesbos, Weberspruit, Lone Creek, Coopers Creek and DR de Wet streams.

E coli counts higher than >10 were recorded in the Vertroostings (70 counts /100 mℓ) and Klein Sabie (26 counts /100 mℓ) streams. During low flow, counts of higher th an 10 per 100 mℓ were recorded at 11 of the 16 sites (73%), and >100 at three site. The three sites with counts >100 during low flow included in order of magnitude Klein Sabie (2000 counts/100 mℓ), Goudstroom (180 counts/100 mℓ) and Vertroostings (140 counts/100 mℓ).

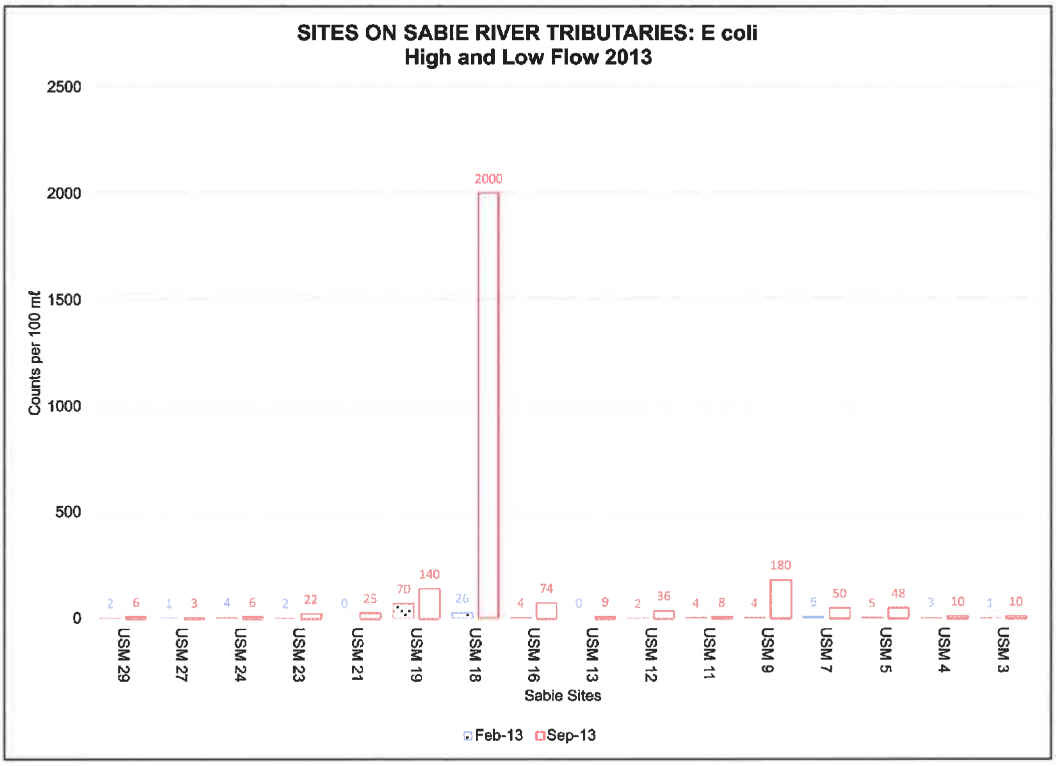


Figure 5-30: E coli values for sites located on the main tributaries of the Sabie River. Site USM 29 is located in the headwaters at Jantjiesbos and USM 3 in the Mac-Mac River at Brandwag.

5.2.10 Free and Saline Ammonia (NH_3)

Detection limit from the laboratory results was 0.2 mg/ℓ. None of the sites sampled had values above these limits during both the high and low flow sampling periods.

5.2.11 Sodium (Na)

Historical results suggests a steady increase in sodium levels from 1995 onwards (Figure 5-31). The highest values are generally recorded in September and the lowest in June.

Results for the 2013 monitoring are graphically illustrated for sites located in the main Sabie River from Headwaters (USM 31) to Aand-de-Vliet (USM 1), and for tributaries of the Sabie River from headwaters to the Mac-Mac confluence.

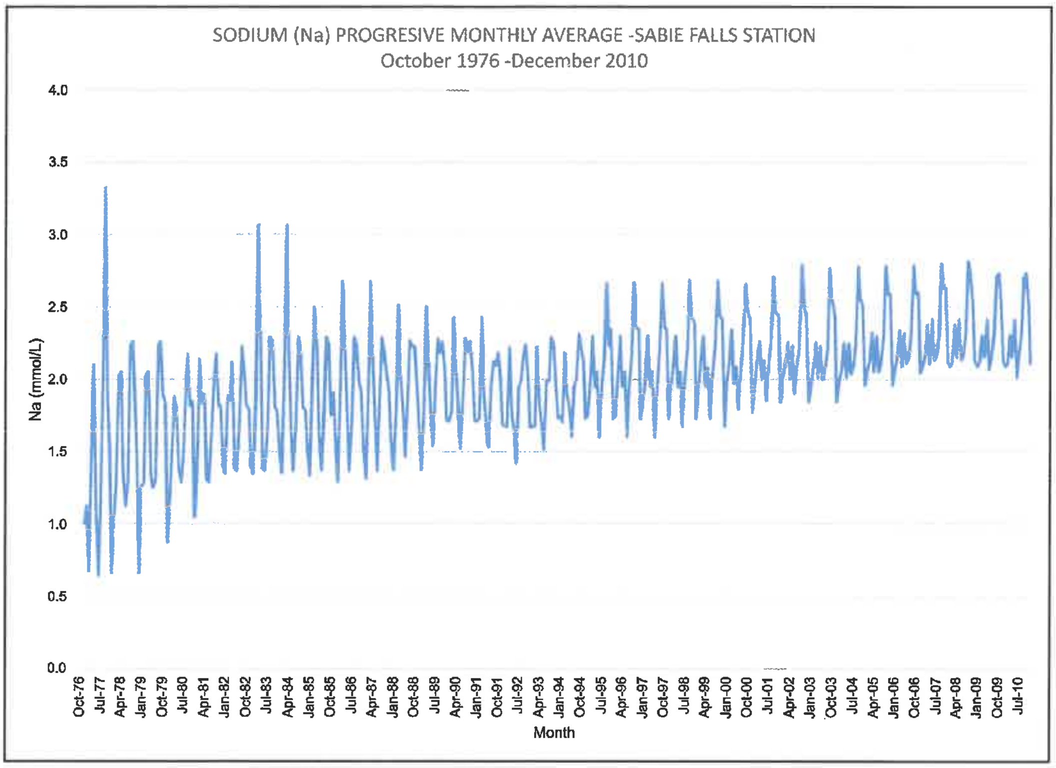


Figure 5-31: The progressive month ly average Sodium (Na) values measured at the Sabie Falls Gauging station from October 1976 to December 2010.

5.2.11.1 Sabie River

Sodium levels in the Sabie River measured in February and September 2013 were similar for low and high flow conditions, with an increase from DR de Wet-Sabie onwards. The highest value was recorded at the Aand-de-Vliet site during high flow conditions.

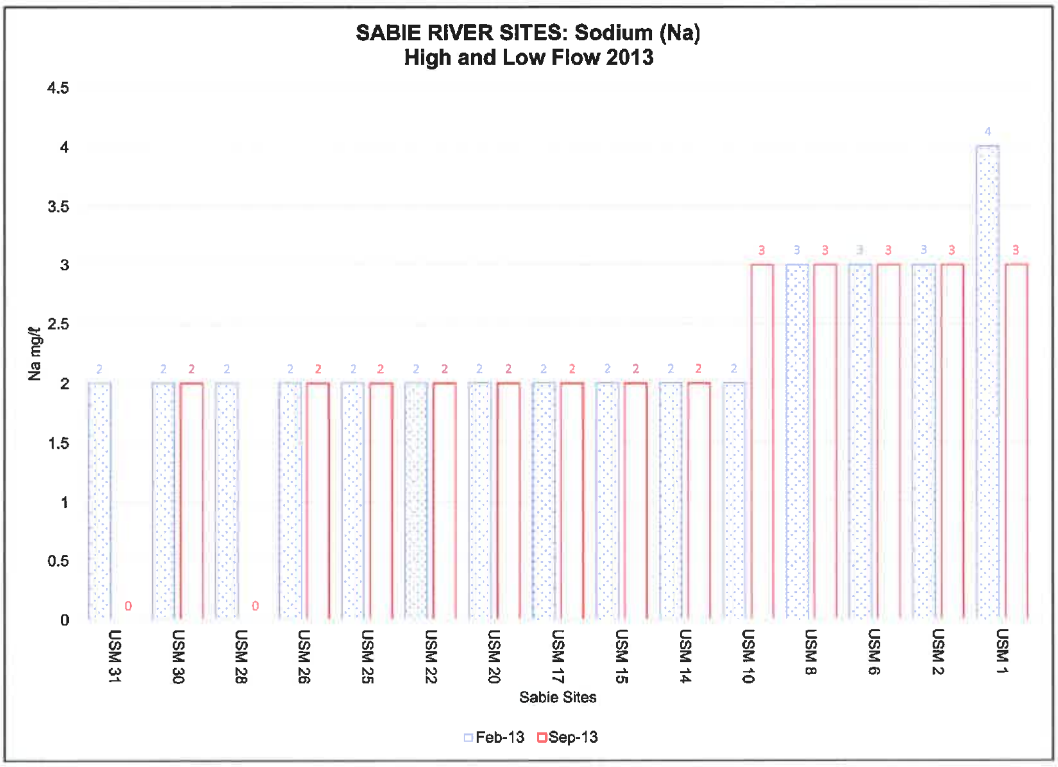


Figure 5-32: Graphical illustration of the sodium measurements for sites located on the Sabie River. Site USM 31 is located in the headwaters and USM 1 at Aand-de-Vliet.

5.2.11.2 Sabie River Tributaries

Sodium measured were below the detection limit in the Jantjiesbos and Bridal Veil streams, during both the low and high flow sampling event. The highest sodium levels were recorded in the Malieveldspruit, Goudstroom, KaMahukwane, Buffelspruit and Sabaan Rivers.

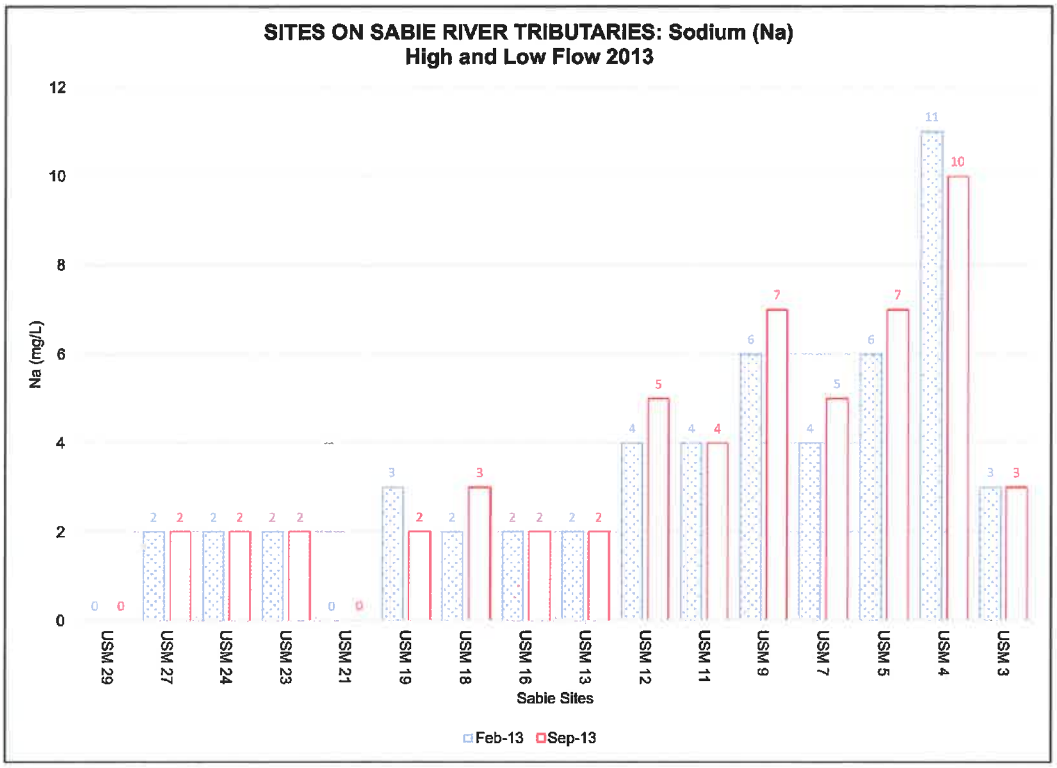


Figure 5-33: Sodium values for sites located on the main tributaries of the Sabie River. Site USM 29 is located in the headwaters at Jantjiebos and USM 3 in the Mac-Mac River at Brandwag.

5.2.12 Copper (Cu)

Detection limit from the laboratory results was 0.025 mg/ℓ. None of the sites sampled had values above these limits during both the high and low flow sampling periods.

5.2.13 Iron (Fe)

Historical results for the Sabie Falls site on the Sabie River suggests a steady increase in iron levels (Figure 5-34). The highest values are generally recorded in September and the lowest in June.

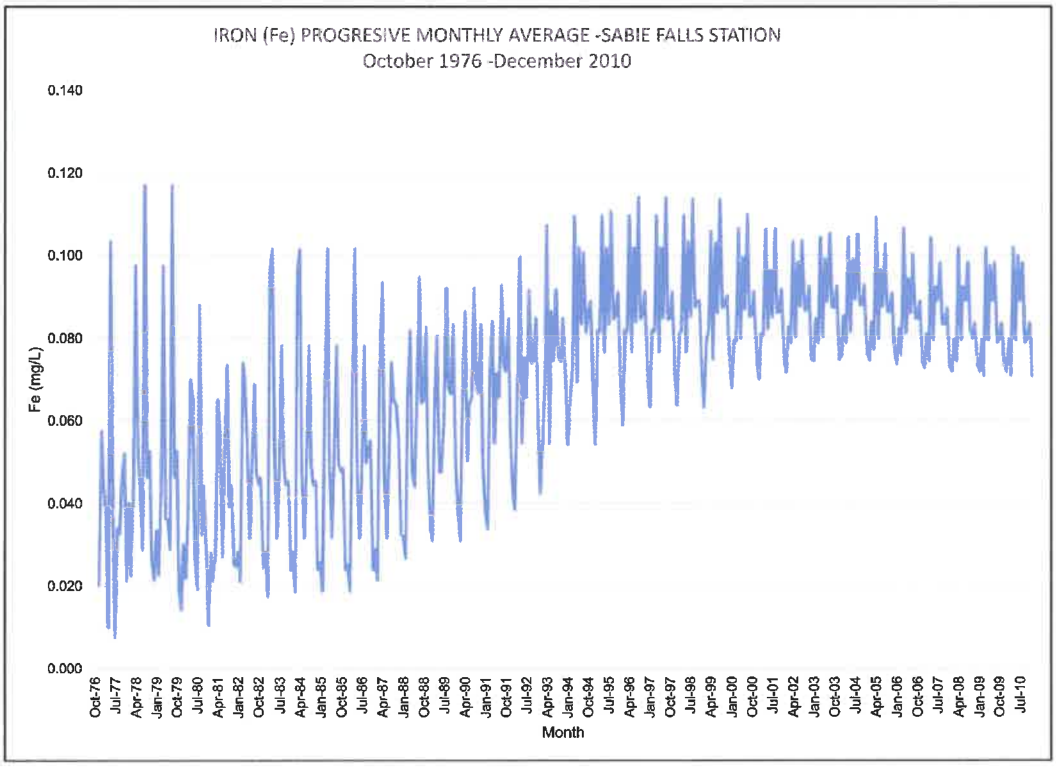


Figure 5-34: The progressive monthly average Iron (Fe) values measured at the Sabie Falls Gauging station from October 1976 to December 2010.

5.2.13.1 Sabie River Sites

During high flow conditions (February 2013), iron levels slowly increase the further one moves away from the source. There were more variance in iron values recorded on the river continuum during the low flow monitoring. In general, iron values measured was higher during the high flow sampling event, but there were exceptions. Iron values were more elevated during low flow than high flow at the site below Horseshoe Falls (USM 26) and the Aand-de-Vliet site (USM 1). The highest iron values were recorded at the Aand-de-Vliet site. Values indicated as zero are below the detection limit (<0.025 mg/ℓ).

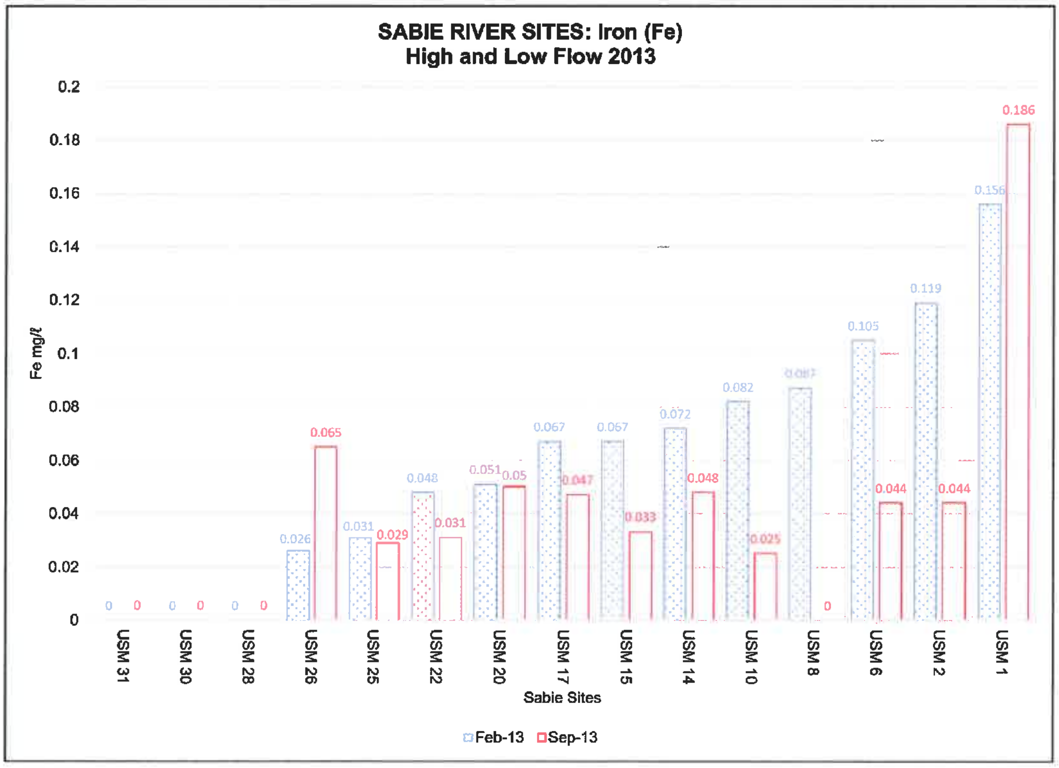


Figure 5-35: Iron values for sites located on the Sabie River. Site USM 31 is located in the headwaters and USM 1 at Aand-de-Vliet.

5.2.13.2 Sabie River Tributaries

In general, iron levels recorded were higher during the low flow sampling event than recorded during high flow. Tributaries where iron levels were higher during low flow included Lone Creek (USM 24), Manyeleti (USM 23), Vertroostings (USM 19), Klein Sabie (USM 18), Coopers Creek (USM 13), Sabaan (USM 4) and Mac-Mac (USM 3). The highest iron values were recorded in the Sabaan River during September 2013.

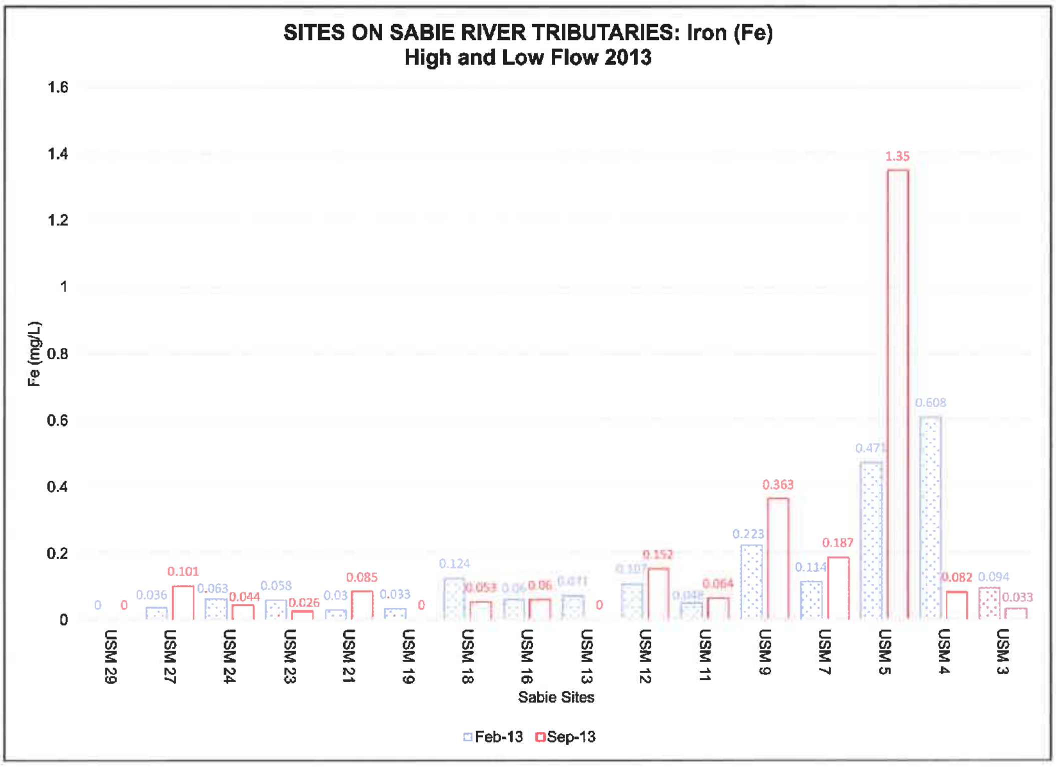


Figure 5-36: Iron levels for sites located on the main tributaries of the Sabie River. Site USM 29 is located in the headwaters at Jantjiebos and USM 3 in the Mac-Mac River at Brandwag.

5.2.14 Manganese (Mn)

Manganese levels analysed by WaterLab was undetectable below 0.025 mg/l. Levels were only detected during high flow conditions (February 2013). On sites located on the Sabie River, Manganese were detected at the Sabie Sewage Farm (USM 17) and Rietfontein Mine (USM14) sites. On the tributaries of the Sabie River, manganese levels were detected at the Klein Sabie (USM 18) site.

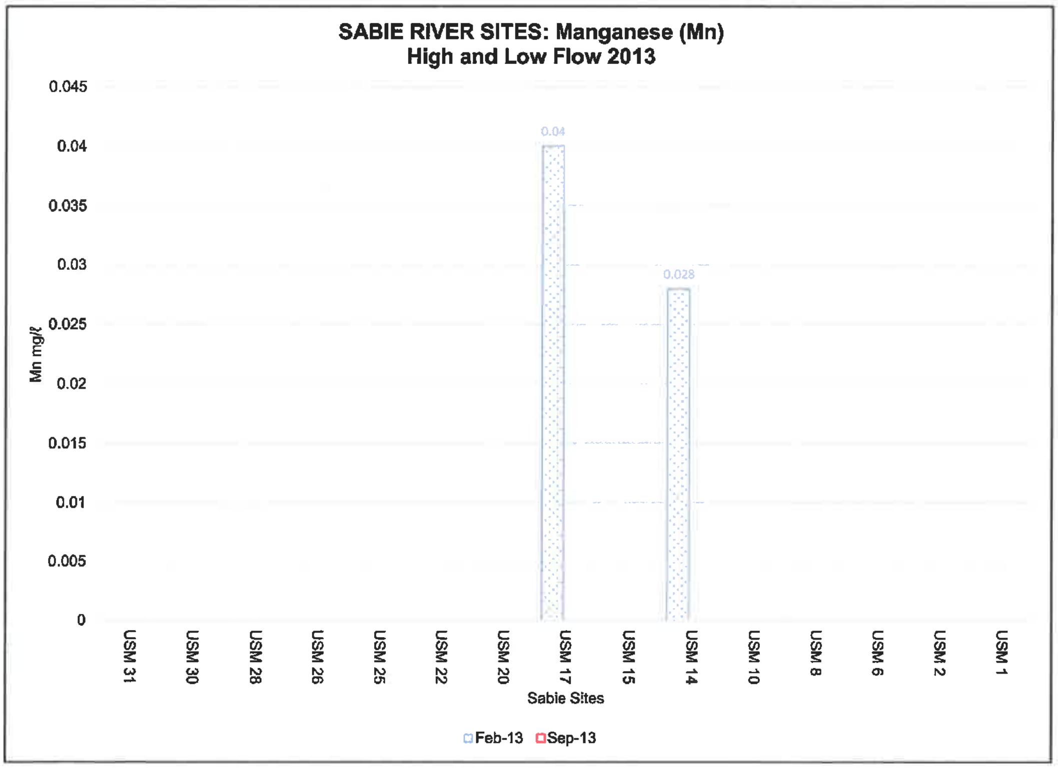


Figure 5-37: Manganese levels for sites located on the Sabie River. Site USM 31 is located in the headwaters and USM 1 at Aand-de-Vliet.

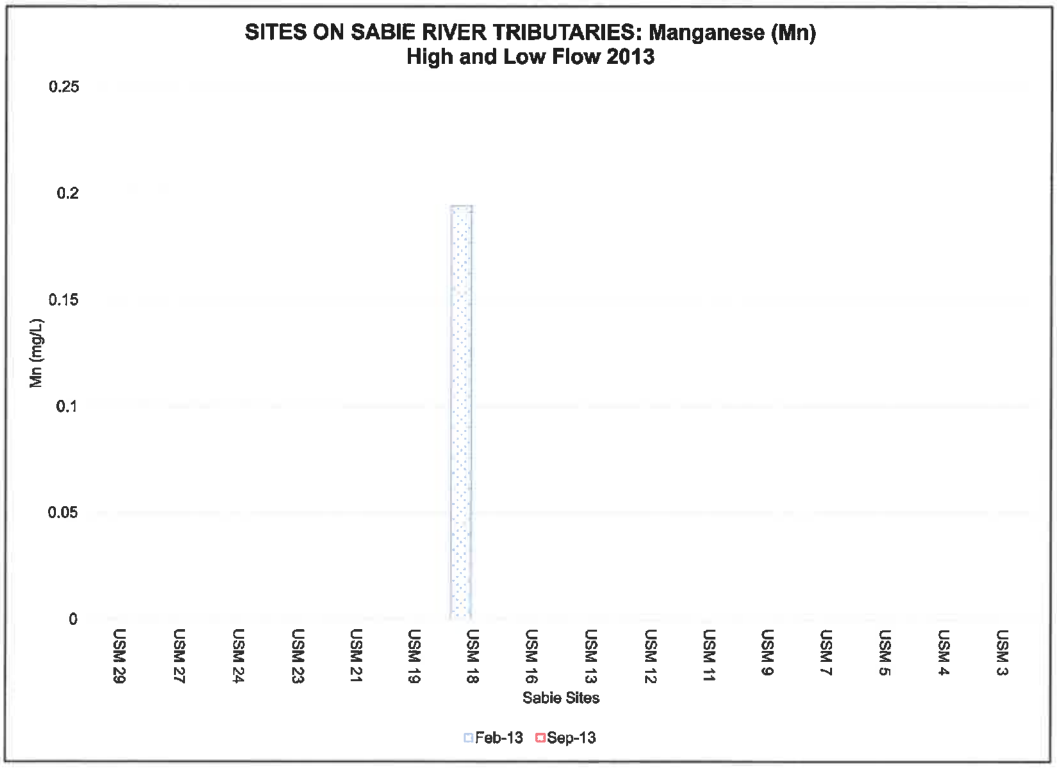


Figure 5-38: Manganese values for sites located on the main tributaries of the Sabie River. Site USM 29 is located in the headwaters at Jantjiebos and USM 3 in the Mac-Mac River at Brandwag.

5.2.15 Water Clarity

Water clarity is a measure of turbidity, measuring light penetration in the water body. The clarity tube measures up to 120 cm, meaning that all results indicating 120 cm clarity are actually more than 120.

Results indicate natural clear waters in the upper reaches of the Sabie River during high and low flow conditions at the Sabie-Headwaters (USM 31), Long Tom (USM 30), Above Horseshoe Falls (USM 28) and Below Horseshoe Falls (USM 26) sites. At the Rietfontein Mine site (USM 14), water clarity was >120 cm during high flow conditions.

In high flow, water clarity deteriorates along the river continuum from the Sabieshoek site (USM 25) onwards. During low flow, water clarity also starts deteriorating from Sabieshoek towards the Sabie Sewage site (USM 17), but water clarity improves further downstream from the Sewage Farm site.

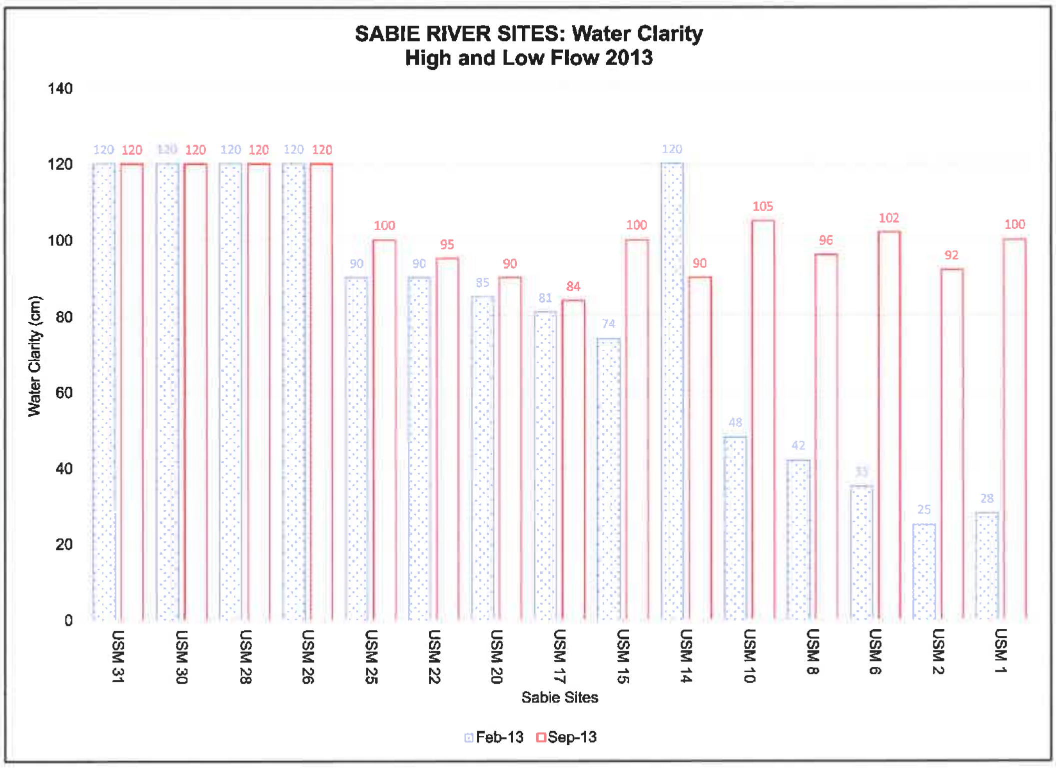


Figure 5-39: Water clarity measured at sites located on the Sabie River. Site USM 31 is located in the headwaters and USM 1 at Aand-de-Vliet.

In the tributaries of the Sabie River, water clarity was >120 cm during both the high- and low flow surveys in the Jantjiesbos (USM 29), Weber's Spruit (USM 27) and Lone Creek (USM 24) streams. Water clarity was only >120 cm in the Bridal Veil (USM 21) and Coopers Creek (USM 13) streams during high flow conditions, and in the DR de Wet stream (USM 11) only during low flow. The worst water clarity during high flow was measured in the Vertroostings stream (USM 19), and during low flow in the Buffelspruit (USM 5).

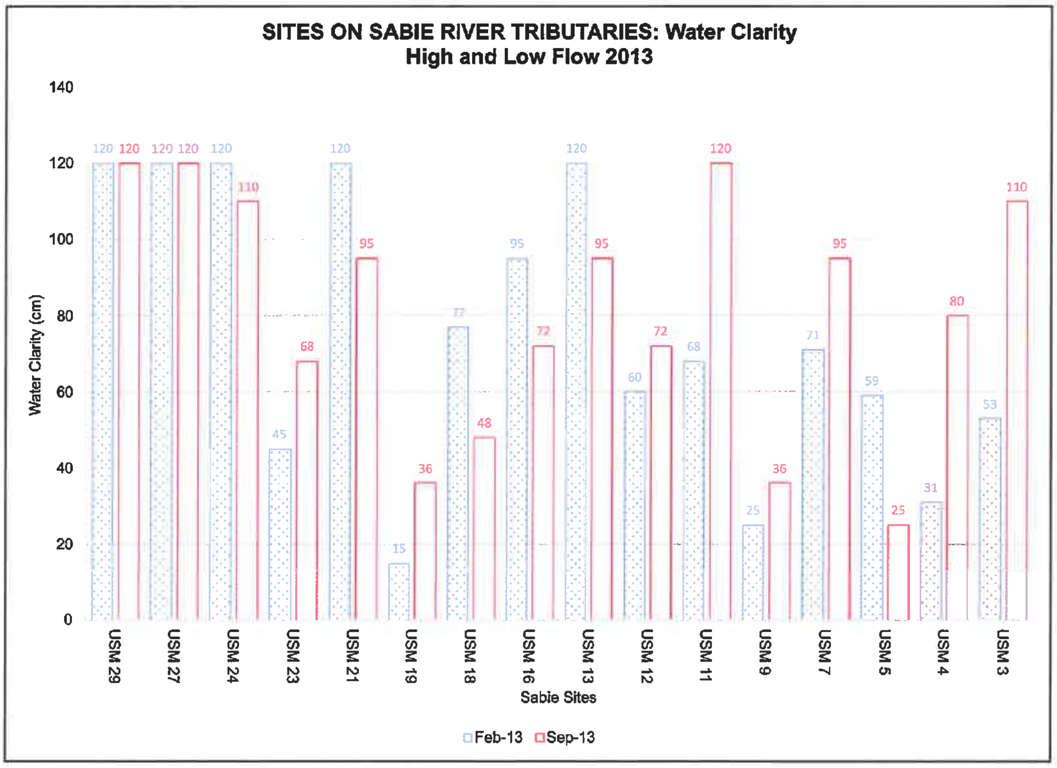


Figure 5-40: Water clarity measured at sites located on the main tributaries of the Sabie River. Site USM 29 is located in the headwaters at Jantjiebos and USM 3 in the Mac-Mac River at Brandwag.

5.3 BIOTA

5.3.1 Fish

Detailed information with discussions are included in the fish specialists report attached (Appendix E). Table 5-2 lists the fish species expect ed and recorded at the six sampling points and Figure 5-41 illustrates the FRAI results during the high and low flow sampling events.

At the site sampled above Sabie Falls (USM 25), species diversity and abundance was greater during high flow than low flow.

At the Sabie Sewage Farm site (USM 17), four of the species expected to occur were absent. A higher diversity (4 spp.) was recorded during high flow than during low flow (3 spp.).

At the Rietfontein Mine site (USM 14), four of the expected eight species were absent during high and low flow. Species abundance was considerably higher during high flow period than low flowperiod sampling events.

Most of the fish species expected ($^{8}/_{9}$) were present during the high flow sampling event, but only six of the nine expected species during low flow. Abundance of fish (CPUE) was greater during the low flow sampling event.

At the Brandwag site (USM 2), only 14 of the expected 21 fish species were recorded during high flow conditions, and 11 during low flow. Abundance of fish (CPUE) were similar for the different flow regimes.

At the Aand-de-Vliet si te (USM 1), 16 of the expected 26 fish species were recorded during high flow, and 15 during low flow. The abundance of fish (CPUE) was greater during the low flow sampling event than during high flow.

Overall, conditions based on the fish community improved from the uppermost (USM 25) site to the site furthest downstream (USM 1).

Table 5-2: A summary list of fish species expected to occur at each site and reach, with the results listed for the high flow (Feb 2013) and low flow (Sep 2013) sampling events. Expected (EX) species per site are indicated, and the number of individual species recorded during the high flow (HF) and low flow (LF) periods are indicated.

EXPECTED SPECIES	SQ REACH																		TOTAL	
	X31A-00799			X31B-00757									X31D-00772							
	USM 25			USM 17			USM 14			USM 8			USM 2			USM 1				
	EX	HF	LF	EX	HF	LF	EX	HF	LF	EX	HF	LF	EX	HF	LF	EX	HF	LF	HF	LF
MORMYRIDAE																				
Marcusenius macrolepidotus													F	7	4	F	9	5	16	9
Petrocephalus wesselsi													F	5		F	6	3	11	3
ANGUILLIDAE																				
Anguilla mossambica	F			F			F			F	1		F	1		F			2	
CYPRINIDAE																				
Mesobola brevianalis													F			F				
Opsaridium zambezense													F	13		F	15		28	
Barbus anoplus	F	18	23	F			F			F	7	14	F			F			25	37
Barbus argenteus																F	8	14	8	14
Barbus brevipinnis													F	7		F			7	
Barbus eutaenia													F	23	32	F	25	19	48	51
Barbus trimaculatus													F	9	16	F	11	14	20	30
Barbus unitaeniatus										F	4		F			F	4		8	
Labeobarbus marequensis													F	26	6	F	24	3	50	9
Labeobarbus polylepis													F	11	28	F	5	15	16	43
Labeo cylindricus													F	14	13	F	17	9	31	22
Labeo molybdinus																F	4	1	4	1
Varicorhinus nelspruitensis				F	6	3	F	28	9	F	8	17	F		19	F		9	42	57
CHARACIDAE																				
Micralestes acutidens													F	36	44	F	41	66	77	110
AMPHILIIDAE																				
Amphilius natalensis	F	3		F			F			F			F						3	
Amphilius uranoscopus	F	8	2	F	1		F	2	1	F	17	7	F	13	16	F	3	14	44	40
CLARIIDAE																				

EXPECTED SPECIES	SQ REACH																		TOTAL	
	X31A-00799			X31B-00757									X31D-00772							
	USM 25			USM 17			USM 14			USM 8			USM 2			USM 1				
	EX	HF	LF	EX	HF	LF	EX	HF	LF	EX	HF	LF	EX	HF	LF	EX	HF	LF	HF	LF
Clarias gariepinus													F			F				
MOCHOKIDAE																				
Chiloglanis anoterus				F	8	2	F	11	3	F	17	9	F	36	41	F	24	31	**96**	**86**
Chiloglanis paratus																F	13	12	**13**	**12**
Chiloglanis swierstrai																F				
SALMONIDAE																				
Salmo trutta																				
Oncorhynchus mykiss																				
CICHLIDAE																				
Pseudocrenilabrus philander				F			F			F	5	18	F	29	26	F	29	26	**63**	**70**
Tilapia sparrmanii		7	3	F	3	12	F	6	8	F	11	10	F			F			**27**	**33**
Tilapia rendalli																F				
Oreochromis mossambicus																F				
NUMBER OF SPECIES	**5**	**4**	**3**	**8**	**4**	**3**	**8**	**4**	**4**	**9**	**8**	**6**	**21**	**14**	**11**	**26**	**16**	**15**	**37**	**37**
NUMBER OF INDIVIDUALS		**36**	**28**		**18**	**17**		**47**	**21**		**70**	**75**		**230**	**245**		**238**	**241**	**639**	**627**
Minutes		**26**	**30**		**30**	**26**		**27**	**28**		**36**	**28**		**28**	**30**		**34**	**32**		
CPUE		**1.4**	**0.9**		**0.6**	**0.7**		**1.7**	**0.8**		**1.9**	**2.7**		**8.2**	**8.2**		**7.0**	**7.5**		
% FRAI		**70**	**63**		**74**	**61**		**77**	**71**		**76**	**70**		**81**	**78**		**83**	**80**		
CLASS (FRAI)		**C**	**C/D**		**C**	**C/D**		**C**	**C**		**C**	**C**		**B**	**B/C**		**B**	**B**		

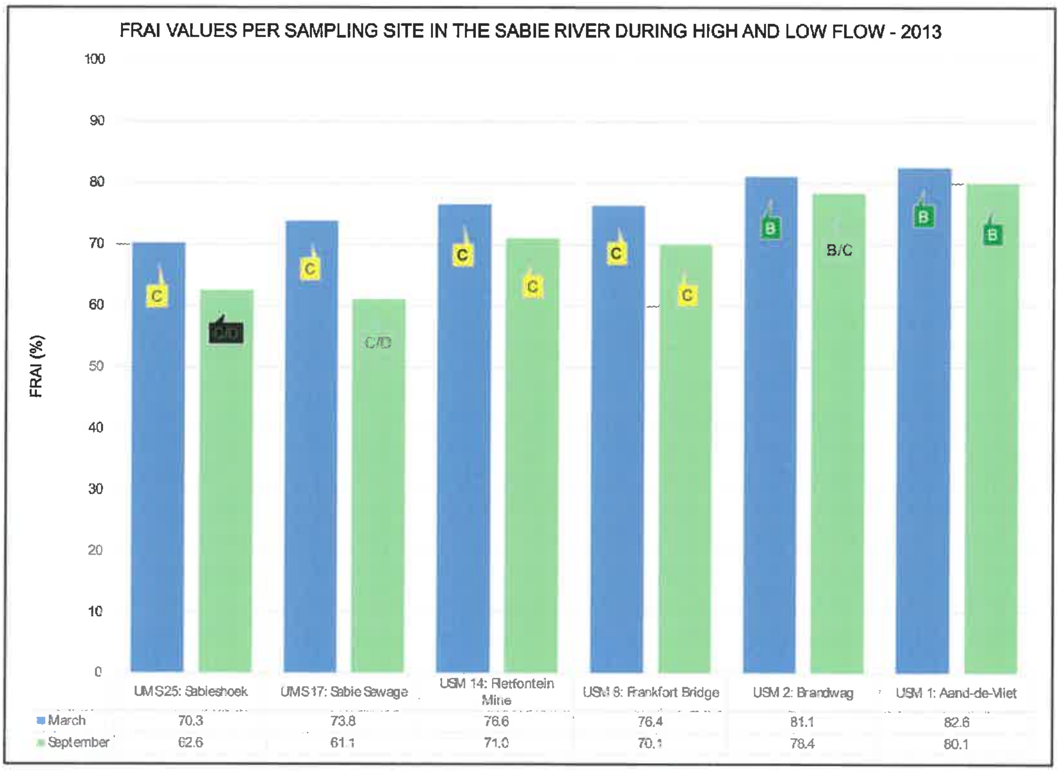


Figure 5-41: Combined graph for the March and September 2013 FRAI values of the biomonitoring sites located in the Upper Sabie River.

5.3.2 Crabs

The crab species recorded form the Sabie-Headwater site (USM 31) to Aand-de-Vliet (USM 1) were Potamonautes sidneyi Rathburn, 1904. On the crab gills, rotifers, sessile ciliates and nematode were recorded.

5.3.2.1 Rotifers

The phylum Rotifera comprises 2,030 known species classified in three classes. Members of the class Seisonidae, with one marine genus Seison, are epizoic on crustaceans and are the only representatives of the Rotifera where reproduction is strictly bisexual (Ricci et al. 1993). In the Class Monogontonta 1,570 species are known and of the exclusively parthenogenetic class the Bdelloidea, 461 clonal species have been described (Segers 2007). Many rotifer species live in close association with plants or other animals, but few of these are truly parasitic actually harming their hosts (May 1989).

Rotifers play a pivotal role in many freshwater ecosystems (Segers 2008) and have been used as bio-indicators. Their most important use as bio-indicator is in the decline of water quality. Rotifers are particularly vulnerable to eutrophication and salinisation. Regarding water pollution by pesticides, there are numerous laboratory studies on rotifer ecotoxicology. According to Segers (2008) the effects of pollutants on rotifer diversity in natural systems have also been studied. Rotifers are often less sensitive to insecticides than cladocerans and their sensitivity to specific compounds varies widely. Due to the large dispersal and colonization capacities of many species, rotifers are easily transported to new habitats by man. Besides this, rotifers have hardly been used in biodiversity assessments and conservation, notwithstanding their economic relevance in aquaculture (Segers 2008).

Rotifera remains a highly diversified taxon, found primarily on a variety of aquatic micrometazoans which live in all types of water habitats, even including the water film surrounding soil particles, mosses and lichens (Fontaneto et al. 2004).

Both marine and freshwater crustaceans have been found to be infested with epizoic and parasitic rotifers, most commonly found on freshwater Cladocera (May 1989). Some were found as ectoparasites on marine shrimps, on the appendages of freshwater lice, with a variety of species known from the branchial cavities of freshwater crayfish. Concerning crabs, a few rotifer species have been found in the branchial chambers of marine and fresh water species (May 1989). Thane-Fenchel (1966) observed that Proalespaguri was found on the gills of a hermit crab, where it was observed to suck on the gill epithelium. When these rotifers where lightly pressed under a cover glass, they expelled some of the host epithelial cells. This was not observed in the crabs dissected from South Africa. In the case of the latter, the rotifers were swimming all over the gill surface and it seemed that they were filtering food from the surrounding water on the slide or in the petri dish. May (1989) came to the conclusion that most rotifers take advantage of the increased food supplies and transportation provided by the hosts on which they occur, a conclusion also share d by this study after observing the rotifers on the Sabie River crabs.

According to Fontaneto et al (2004) some rotifer-host associations are species-specific, especially in the case of rotifer species found as epizoics on the family Potamonidae, but to date the information available to prove this is still very scarce. The only record to compare the rotifers found on the Sabie River crabs with are those collected from Italy, which were found associated with *Potamon fluvia tile*. These rotifers belonged to the class Bdelloidea and were found on the gills, and none were recorded on the other body parts. Two species were found on the Italy crabs, i.e. *Lecane branchicola* (Lecanidae) and *Embata parasitica* (Philodinidae). In the case of Lecane more than 70 species have an Afrotropical distribution and although *L. branchicola* does not occur in this area, this is the only species of the genus known from the gills of freshwater crabs. None of the five Embata species occur in the Afrotropical region (Segers 2007).

Following the keys of Ruttner-Kolisko (1974), Pennak (1978) and Thorp & Covich (1991) the rotifers found on *P. sidney* were identified as belonging to the class Monogononta, order Ploima (which are rotifers with a typically posterior foot and two toes) and the family Epiphnidae, most likely the genus Epiphanes.

Table 5-2 and 5-3 summarise the distribution of the symbionts found on the two occasions when crabs (*P. sidneyi*) from the Sabie River were dissected. Of the total of 65 crabs that were dissected, only three individuals did not host any symbionts at all. No symbionts were found on any of the body appendages, except on the gill arch and lamellae of the crabs. The second batch of crabs that were analysed in September were also sexed and weighed, but no correlation was found regarding the presences of symbionts and the weight or sex of the crab s. Not all of the 12 gill arches per crab were infested to the same extent. The rotifer symbionts were not found on the gill lamellae, but were concentrated on the anterior and posterior margin of the gill arch (see Figures 5-42A, B & E). In some case some of these filaments did not harbour any symbionts. In some cases where a higher infestation per crab was observed, six or more of the gills were infested and in two cases all 12 gill arches were infested.

In the majority of the cases a low infestation, with only up to 20 rotifers were found attached to the anterior margin of the arch, representing a surface area of 5% of the gill arch margin. A total of 54 crabs from all the 11 localities had infestations falling in this category. Of the total of 65 crabs, six had a slightly higher infestation (up to 80 rotifers on the anterior side if the arch, Figure 5-42A) that presents a surface area of 70% of the anterior gill arch margin. Five of the crabs had more than 100 rotifers on the anterior as well as posterior side of the gill arch covering more than 90% of the gill ach margin. In the majority of the cases the rotifers were attached to the gill arch anterior margin (Figures 5-42E & F) and only in a few cases were small colonies found at the tips of the filaments (Figure5-42C). Some individuals also detached from the gills and swam actively in the petri dish (Figure5-42D), suggesting that these rotifers are not true parasites, but probably only attach to the gill arch for transport and food.

5.3.2.2 Sessile Ciliates

Many ciliate species (apostomatids, peritrichs, suctorians, heterotrichs and chonotrichs) have been reported from a variety of crustacean host (Fernandez-Leborans 1997). The majority of former studies focused on species descriptions, and only a few papers deals with the ecology or relationship with the host. In the study conducted by Fernandez-Leborans (1997) on the blue crab, he found that Zoothamnium and Cothurnia specimens were found randomly on the crab body. In the case of Chilodochona they mostly occurred on the buccal appendages. This was unexpected, as in most cases the gill surfaces is the most common place for epibiotic ciliates and the absence of ciliates from the gills on the crabs in the s tudy done by Fernandez-Leborans (1997) was unexplained. This is in contrast to what we observed for the South African crabs, were the bodies and appendages of the crabs hosted no symbionts and sessile ciliates were found only the gill lamellae.

Peritrichous ciliates of the genera Lagenophrys, Epistylis (Epistylididae) and Zoothamnium (Vorticellidae) have been recorded from the gill lamellae of marine and freshwater crabs.

Lagenophryidae: Loricate, solitary, stalkless, lorica in shape of flattened hemisphere, with surface glued to host's integument.

Epistylididae: Generally stalked, with stalk often non-contractile (but with highly contractile body), solitary or colonial, zooids can be up to 600 µm in size, abundant in freshwater habitats, free-living or symphorionts on diverse host range.

Vorticellidae: With contractile stalk, all species colonial except for 2 genera. Zooids not independently contractile among colonial forms, species attach to inanimate objects as well as plants and aquatic animals.

More than 51 Lagenophrys species have been described from a variety of crustacean hosts, demonstrating a high degree of host-specificity (Crouch 1966). This is even justifiably used as taxonomic criterion in species descriptions of Lagenophrys species, well before molecular studies were developed (Corliss & Brough 1965). In the case of Epistylis they are found as epibionts of molluscs, fish, amphibians and crustaceans, thus they are less host-specific. Crouch (1966) found that an increase in the numbers of epibionts, combined with additional infections of endoparasites, low oxygen tension in warmer water, overcrowding of the crabs and injuries can all contribute to general anoxia in crabs.

Thirteen of the 65 crabs from the Sabie River had a very low infestation of sessile ciliates; we found only one colony of ciliates per gill lamellae on one of the gills. The ciliates were identified as belonging to the genus Epistylis (Peritrichia: Epistylididae), due to the non-contractile stalk, shape of the body and nuclear apparatus. Two forms were observed, one with a more slender stalk with two zooids (Figure 5-41A), and a second representative which had a shorter, more stubby stalk, branching into more zooids (Figures 5-41B-D).

5.3.2.3 Nematoda

In three of the samples dissected (see Table 5-2 at USM 06 and Table 5-3 at USM 06 headwaters) we found a few nematodes. Holovachov et al. (2010) found an epibiotic nematode associated with a gastropod, but did refer to other epibiotic nematodes known from crabs. It seems that representatives of the Order Monhysterida do occur on the gills of land crabs (although these were recorded from the Caribbean). It was first found in the early 1920's, but has since been recorded more in the literature. The only other reference to epibiotic Nematode on crabs was by Chesunoc (1987), but also from land crabs.

Holovachov et al. (2010) came to the conclusion that the exact mechanism of symbiotic associations of nemat odes with aquatic invertebrates (snails in their case) are unknown. It seems possible that the nematodes find food and shelter on the hosts, and that could be the same for the few nematodes that were found crawling over the gills from the Sabie River crabs.

Table 5-3: Symbionts found on *Potamonauteus sidneyi* from Sabie River South Africa, during the March dissection. 1x = low infestation, up to 20 individuals, 2x slightly higher infestation and 3x represents where the entire gill arch were covered by rotifers.

USM 31 Headwaters	**USM 06 Lunsklip**	**USM 17 Sewage**
1) DEAD ON ARRIVAL, 1x rotifers	1) 1x rotifers	1) 2x of rotifers
2) 1x rotifers	2) Nematode, small	2) 2x rotifers
3) 1x rotifers	3) 1x rotifers	3) 1x rotifers
4) 1x rotifers	4) 1x rotifers	4) 2-3x rotifers
5) 1x rotifers	5) 1x rotifers, few Nematode worms	5) 1x rotifers
6) 1x rotifers	6) DEAD ON ARRIVAL, not intact anymore, not possible to dissect	6) 1x rotifers
USM 25 Sabieshoek	**USM 14 Rietfontein Mine**	**USM 01 Aand-de-Vliet**
1) Crab almost dead; 1x rotifers	1) no symbionts	1) 2x rotifers; Ciliates (1 colony)
2) 1x rotifers	2) 1x rotifers	2) 2x rotifers
3) 1x rotifers	3) no symbionts	3) 3x rotifers; ciliates (1 colony)
4) 1x rotifers	4) 1x rotifers	4) 1x rotifers; ciliates (1 colony)
5) 1x rotifers	5) 1x rotifers; 1x Ciliates	5) 1x rotifers; ciliates (1 colony)
6) 1x rotifers	6) 1x rotifers; Few ciliates zooids	6) 2x rotifers; Ciliates (1 colony)

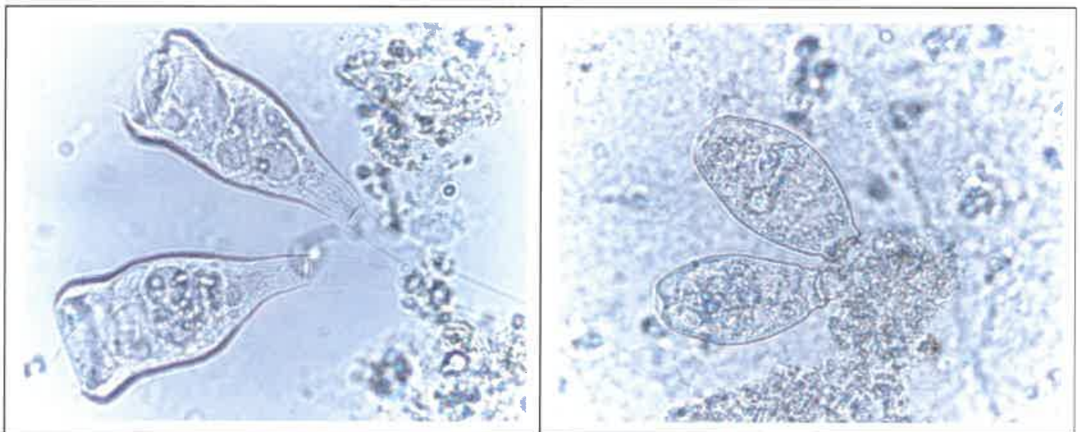
Table 5-4: Symbionts found on *Potamonauteus sidneyi* from Sabie River South Africa, during the September dissection. 1x = low infestation, up to 20 individuals, 2x slightly higher infestation and 3x represents where the entire gill arch were covered by rotifers.

USM3	**USM 31 Headwaters**	**USM 2**
1) Male 25.9 g	1) Male 18.6 gr	1) Male 17.9 g

1x rotifers	no symbionts	1x rotifers
2) Female 23.8 g 1x rotifers; few loose ciliate zooids	2) Female 41.9 g gravid 2 worms, Nematodes	2) Male 17.2 g 1x rotifers
3) Female 20.9 g 1x Ciliates	3) male 36.4 g 1x rotifers	3) Female 16.9 g 1x rotifers
4) Female 24.9 g 1x rotifers	4) Male 21.6 g 1x rotifers	4) Male 30.4 g, gills dirty 1x rotifers
5) Female 23.9 g 1x rotifers	5) Female 61 g 1x rotifers	5) Male 32 g 1x rotifers
6) Female, 33.7 g 3x rotifers	6) Male mature 53.9 g 2x rotifers	6) Male 31.6 g gills dirty (algae on ridge) 1x rotifers

USM 25 Sabieshoek	**USM 17 Sewage**
1) Male 30.3 g 1x rotifers	1) Male 22.9 g 1x rotifers
2) Male 18.1 g 3x rotifers	2) Female 34.2 g. leech on leg of crab 1x rotifers Ciliates (1 colony)
3) Female 22 g (all of the gills, cover groove) 3x rotifers	3) Male 30.4 g 3x rotifers (all the gills, cover groove)
4) Female 25.9 g 1x rotifers	4) Male 22.6 g 1x rotifers ciliates (1 colony)
5) Male 21.5 g 1x rotifesa ciliates (1 colony)	5) Female gravid 28 g 1x rotifers ciliates (1 colony)
6) female gravid 27.8 g 2x rotifers ciliates (1 colony)	6) Female 34.2 g gravid 2x rotifers ciliates (1 colony)

Figure 5-42. Light micrographs of peritrichs found on the gill lamellae of *Potamonauteus sidneyi*, collected from the Sabie River, South Africa.



A) Live observation of expanded *Epistylis* sp. with elongated stalk.	B) Two zooids of contracted *Epistylis*sp. with shorter stalk.

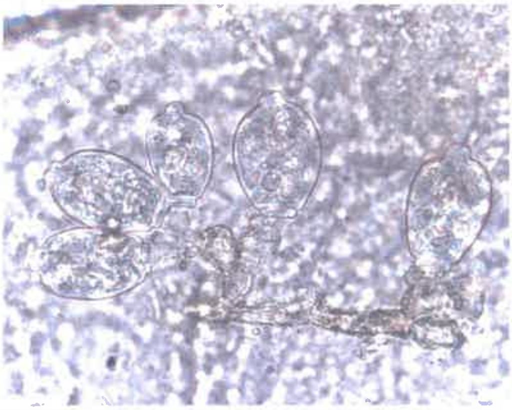
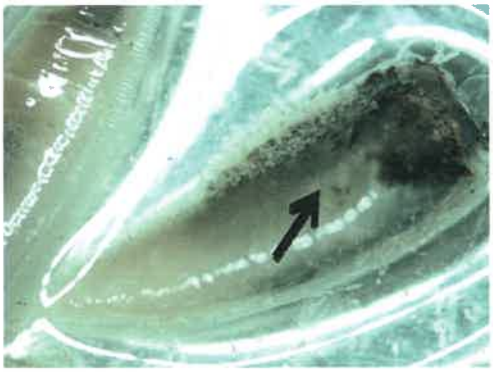
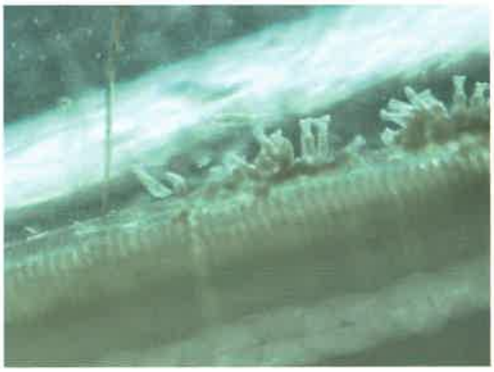
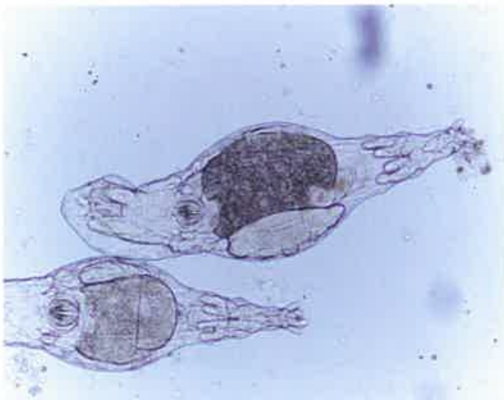
	
C) Live observation of contracted *Epistylis*sp. Colony with short stalk.	D) Haematoxylin stain of *Epistylis*sp, illustrating elongated macronucleus.

Figure 5-43: Light- and Scanning electron micrographs of rotifers found on the gill arch of *Potamonauteus sidneyi,* collected from the Sabie River, South Africa.

	
A) Gill filament and rotifers.	B) Live observation of rotifers on gill.
	
C) Live observation of rotifers.	D) Live observation of individual rotifers.

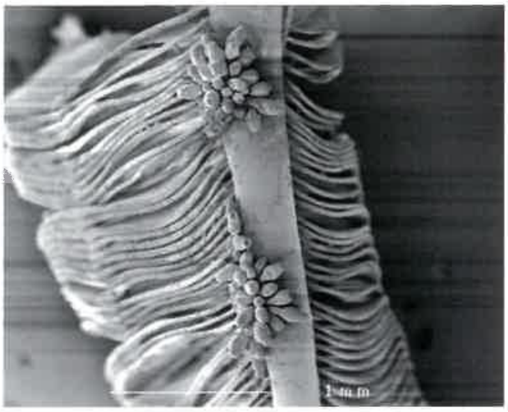
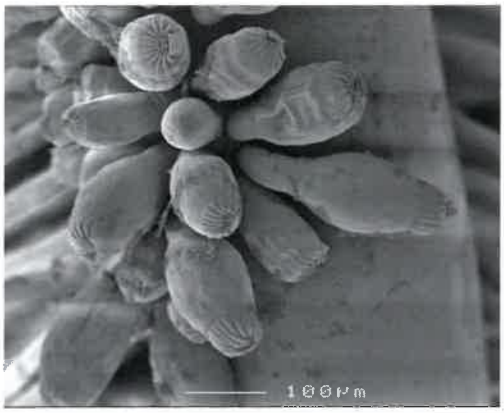
	
E) SEM micrograph of colonies of rotifers on gill arch.	F) SEM micrograph, close up images of rotifers.

Table 5-5: Data from Table 5-3 are summarised. Rotifers, ciliates and nematodes recorded on the gills of crabs collected during different seasons at the same sampling locations are expressed as a percentage.

SITE	SITE NAME	TAXA	MARCH		SEPTEMBER	
			No.	%	No.	%
USM 31	Sabie-Headwaters	Rotifers	6/18	33.3	5/18	27.8
		Ciliates	0/18	0	0/18	0
		Nematodes	0/18	0	1/18	5.6
		Total	**6/54**	**11.1**	**6/54**	**11.1**
USM 25	Sabieshoek	Rotifers	6/18	33.3	11/18	61.1
		Ciliates	0/18	0	2/18	11.1
		Nematodes	0/18	0	0/18	0
		Total	**6/54**	**11.1**	**13/54**	**24.1**
USM 17	Sabie Sewage Farm	Rotifers	9.5/18	52.8	9/18	50.0
		Ciliates	0/18	0	4/18	22.2
		Nematodes	0/18	0	0/18	0
		Total	**9.5/54**	**17.6**	**13/54**	**24.1**
USM 14	Rietfontein Mine	Rotifers	4/18	22.2	7/18	38.9
		Ciliates	2/18	11.1	2/18	11.1
		Nematodes	0/18	0	0/18	0
		Total	**6/54**	**11.1**	**9/54**	**16.7**
USM 6	Lunsklip	Rotifers	4/15	26.7		
		Ciliates	0/15	0		
		Nematodes	2/15	13.3		
		Total	**6/45**	**13.3**		
USM 1	Aand-de-Vliet	Rotifers	11/18	61.1	6/18	33.3
		Ciliates	5/18	27.8	0/18	0
		Nematodes	0/18	0	0/18	0
		Total	**16/54**	**29.6**	**6/54**	**11.1**

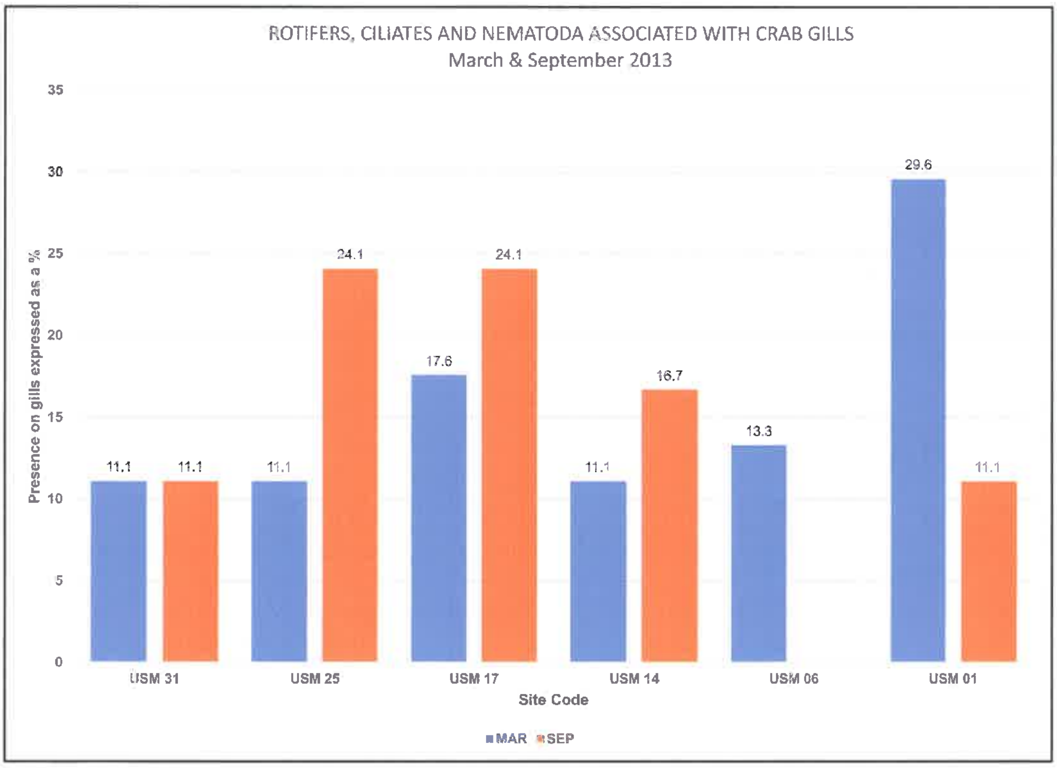


Figure 5-44: Presence of rotifers, ciliates and nematodes on the gills of crabs collected from the different sites expressed as a percentage.

6. DISCUSSION

The deterioration of stream conditions in the Upper Sabie River Catchment as reflected in the 2010/11 biological survey, were attributed to a combination of impacts and events. The entire catchment area experienced devastating uncontrolled fires in 2007. Commercial forests replaced natural grasslands, and the intensity of fires on the soil in these forestry sites are considerably higher than those experienced in natural grassland. This dif ference in fire intensity is mainly as a result of the high build-up of organic material, which is highly flammable. Dense infestations of exotic weeds in commercial tree compartments and riparian zones also supplement fuel loads, with some exotic plant species more flammable (e.g. *Lantana camara* and *Pinus patula*) (Bromilow 2010).

Combined with high catchment drainage densities (induced by high road network densities), the damage to these disturbed areas after uncontrolled fires and high downpours is devastating. High silt loads enter streams in the catchment, and depending on catchment characteristics and management intervention, can take several years to recover.

High silt loads combined with high organic and pollution inputs, further contribute to stress. The detailed monitoring therefore attempted to identify specific sources reflected by specific data collected.

6.1 ROAD AND CATCHMENT DRAINAGE DENSITIES

All of the data is not yet available. Catchment boundaries first had to be delineated on GIS produced maps, in order to determine road network densities for each catchment. This means that the GIS specialists employed by the forestry companies have to specifically generate this information, which takes time.

Some catchment areas fall within different forestry companies, and the data from the different forestry areas needs to be combined.

When the data is finally a vailable, high road network densities will be compared to substrate and instream habitat quality, as well as other variables assessed.

5.2 SEDIMENTS

The organic component in sediment samples collected was high in the headwaters, decreasing in quantity along the river continuum. This is an expected outcome, since the catchment is dominated by forests. High leaf litter input from the forests into small streams drives the food web in these mountain streams. As food gets transported (abiotic processes) and aquatic biota, leaf litter gets broken down to finer material as a food source for downstream biota. The community structure in river systems are driven by these processes (Cummins et al. 2008; Davies et al. 1993; Davies & Day 1998; Vannote et al. 1980).

The Sabie-Headwaters (USM31) and Lunsklip (USM 6) sites stand out in terms of the percentage carbon in the sediments (Figure 5-3). The Sabie-Headwaters site has a very steep gradient, with numerous waterfalls an d cascades. It is therefore expected that any leaf litter inputs will be transported out of the stream at a rapid rate. A small portion of the USM 31 sites catchment is dominated by indigenous forest, with grasslands further upstream dominant. Low levels of organic deposition is therefore expected.

The Lunsklip site (USM 6) has several pool areas between rapids, with the riparian vegetation completely dominated by exotic tree and weed species, specifically *Eucalyptus grandis* and *Lantana camara.* The decomposition of leaf litter from exotic vegetation takes longer to break down than leaf litter from indigenous vegetation, hence the high percentage of carbon in th e sediment. Several studies carried out (some specifically on Eucalyptus trees) highlight this (Abelho & Graça 1996; Graça et al. 2002; Graça 2001; Harrison et al. 1999). The high carbon content in the sediments in pool areas at the Lunsklip site is therefore attributed to the high degree of weed infestation of the riparian zone.

No clear trends are visible from the sediment particle size distribution analysis.

6.3 WATER CHEMISTRY

Based on historical results, it is clear that the wa ter quality at the Sabie Falls and Klein Sabie monitoring points is changing since the first samples were collected in 1976. Interestingly, most of the results fall within the limits stipulated in DWAF's Water Quality Guidelines for Aquatic Ecosystems (DWAF 1996).

6.3.1 pH

Historical pH measurements recorded since 1976 indicated fluctuations in pH values, with increases in pH during low flow conditions, and decreasing pH during high flows (Figure 5-5, Figure 5 -7). Similar observations have been made in the rivers of the Lesotho Highlands Skoroszeweski (1999) and other studies (Vega et al. 1998). During high rainfall events, organic matter (e.g. plant material, animal waste) is washed into river systems.

Organic matter generally gets "trapped" in the pool areas of a river system during low flow conditions (deposition). The decomposition process produces carbon dioxide (CO_2), which combines with water to produce w eak carbonic acids (California Water Quality Resources Board 1963). As the organic material builds up during low flow conditions, so do nutrients and hence algal growth increases. This increase in algal growth means that there is more photosynthesis. The photosynthetic process uses the hydrogen ions (H^+) in the water, reducing H^+ concentrations. When the concentration of H^+ decrease, pH levels increase (Department of Ecology 1994).

Overall, pH levels in the Sabie R iver are increasing (Figure 5-5, Figure 5-6, Figure 5-7, Figure 5-8). This increase could be linked to greater organic inputs as described above, but requires further investigation.

6.3.2 Electrical Conductivity

Historical results generally indicates fluctuations in EC levels during high and low flow conditions (Figure 5-11, Figure 5-13). The increase in water flow during rainfall events could potentially dilute ion concentrations. Increase s in EC values during high flow were recorded in the Sabie River at the site Above Rietfontein Mine and at the Lunsklip site (Figure 5-14). On the Sabie Tributaries, increases in EC values during the high flow monitoring in 2013 was recorded in most of the tributaries (Figure 5-15). Water loss as a result of high evaporation rate can lead to increases in ions (Lesch, 1995).

The water sample on the Sabie River at USM 15, above the Rietfontein Mine, was collected below an active mine. A pe rmanent stream from the mining site drains into the Sabie River. Increased levels of EC during high flow at the USM 15 site are attributed to increased ion inputs from the mine.

Figure 6-1: A tributary from an active mine just downstream from the town of Sabie depositing fine sediments into the Sabie River during low flow conditions (G Diedericks, 18 September 2013).

6.3.3 Chloride

Although chloride levels fall within acceptable limits, the considerable increa se in chloride concentration over time (Figure 5-16, Figure 5-17) are of concern. Chloride levels are often linked to oceanic influence on precipitation (Lesch, 1995). Chloride ions are highly mobile, and are also leached from various rocks into soil and water by weathering. Chloride levels could also increase due to anthropogenic influences such as run-off from animal feeds, septic tanks, effluent, land-fill leachates, industrial effluents and run-off from irrigation.

In samples collected during the low and high flow seasons in 2013, detectable levels (5.0 mg/ℓ) of chloride in the Sabie River were measured at the Below Horseshoe Falls (USM 26) and Rietfontein Mine (USM 15) sites during the high flow season. The Horseshoe site is located downstream from the Horseshoe Falls trout dams, and the Rietfontein Mine downstream from historic and current mining areas.

On Sabie tributaries, elevated levels of chloride were measured in the DR de Wet stream (USM 11) and Buffelspruit (USM 5). During low flow, detectable levels of chloride were measured in the Goudstroom, Buffelspruit and Sabaan Rivers. All of these tributaries are characterised by high silt loads and deposits. Agricultural crops are dominant in large portions of the lower Sabaan River catchment, which could contribute to this.

The steady increase in chloride levels in the Sabie River at the Sabie Falls gauging station is of concern.

6.3.4 Sulphate

Increases in sulphate levels at the Sabie Falls and Klein Sabie gauging stations is apparent since monitoring was initiated in 2 013. Sulphates naturally enter streams through the weathering of rocks, atmospheric deposition and precipitation. Hem (1985) linked increased sulphate level in the Great Lakes of the Lower Mississippi River to increased industrial and agricultural activities.

The highest sulphate levels in the 2013 survey were recorded in the Klein Sabie River during the low flow sampling event. Most of the industrial sites in the Sabie area are located in the Klein Sabie catchment which could contribute to this.

6.3.5 Nitrate

Nitrate levels measured at the Sabie Falls gauging station fluctuate seasonally and have increased since the first monitoring of October 1976. The level of increase is small but steady.

Increased nitrate levels could be attributed to fertiliser use, leakage from septic tanks, sewage inflows and catchment erosion. The highest levels was recorded during high flow, with the highest value in the Sabie River at the Headwater site (USM 31). This trend was reversed during low flow conditions, with the highest nitrate levels recorded downstream from the Sabie Sewage Farm (USM 17).

Nitrate levels at the Klein Sabie site (USM 18) were elevated during low flow in 2013. Sewage drainage pipes run along the Klein Sabie River, and are often blocked and overflowing into the river. It is likely that elevated nitrate levels could be linked to sewage inputs.

6.4 BIOTIC COMPONENT

6.4.1 Fish

The FRAI values obtained from this fish survey during high - and low flow, indicate moderate to largely modified conditions in the upper reaches of the Sabie River, improving as the river flows further eastwards.

At the uppermost fish sampling site (USM 25: Sabieshoek), the fish assemblage is likely to be impacted on by introduced alien rainbow trout (*Oncorhynchus mykiss*) which are regularly stocked for recreational fishing. Several scientific studies worldwide have highlighted significant ecological impacts of introduced exotic fish (Arthington 1991; Cucherousset & Olden 2011; Mitchell & Knouft 2008; Young et al. 2010). Some of these impacts include:

Species behaviour (e.g. fish, aquatic invertebrates, frogs change in microhabitat preference to avoid being exterminated, diel activity, growth rate, etc.);
Morphology (e.g. growth and reproduction rates of all aquatic species);
Transmission of pathogens and/or parasites;
Altered distribution of indigenous species (e.g. displacement from optimal habitat);
Species extinction;
Altered species composition;
Altered food webs, and;
Modify energy fluxes between ecosystems.

(Cucherousset & Olden 2011)

Other than freshwater eels, no piscivores (predatory) fish species naturally occurred in the Sabie River upstream from the Sabie Falls. The evolutionary development of indigenous fish species naturally occurring within this portion of the Sabie River has therefore always excluded piscivores fish. Scientific studies on the predator induced trophic cascades in stream communities have further highlighted the influ ence of piscivores fish on altering trophic stream communities (McIntosh & Townsend 1996; Pace et al. 1999; Turner & Peacor 2012). Also of concern is the introduction of ecto- and endo- parasites through the stocking of alien and invasive species. The endemic fish species in these upper reaches are not adapted to these parasites and in times of stress these parasites have a drastic effect on the indigenous fish species.

Excessive siltation and deposition further reduce av ailable fish habitat. The low ecological class of a class C/D obtained for the low flow period (moderately to considerately impaired) with a moderate diversity of taxa dominated by tolerant species is of concern.

The Sabie River at the USM 17 site located below the towns of Sabie, Simile and the Sabie Sewage Treatment Works is largely impacted by combined impacts of the upstream land-use. Reduced water quality, degraded riparian zones and instream habitat are the key factors influencing stream conditions.

Reduced water quality also has an impact on the fish assemblage recorded at sites USM 14 and USM 8, located further downstream in the Sabie River. Excessive sediment inputs and deposition, combined with shaded riparian zones (historically open woodland), high organic inputs and altered water quality further reduce fish habitat.

At the sites further downstream, USM 2 (Brandwag) and USM 1 (Aand-de-Vliet), the impact of Sabie and Graskop towns, commercial f orestry and other land-use impacts are fairly diluted, although several of the fish species expected were absent.

6.4.2 Crabs

The rotifers and peritrichs found on the gills of *P. sidneyi* are probably more symbiotic than parasitic. In the opinion of the researcher who analysed the crabs, the respiratory area of the crabs are not damaged, thus these symbionts should not have any adverse effect on the crabs. It is thought that they are probably to the advantage of the crab, as the filtering movement of the corona o f the rotifers as well as the filter feeding action of the ciliates probably assist in ventilation of the gills when the crabs are out of the water or in water with low oxygen concentrations.

7. RECOMMENDATIONS

7.1 SEDIMENTATION

Sources of sedimentation are mainly linked to mining (legal & illegal), forestry roads (exacerbated after uncontrolled fires), and altered catchment hydrology (as a result of too many roads). The following recommendations are made in this regard:

7.1.1 Maintain high forestry road standards through improved management

High standards are set for forestry roads, but because of the high road network density it is impossible to maintain these standards. Small district roads are also poorly maintained, and the high traffic volume on these roads promote high sediment inputs into rivers and streams. In order to maintain road standards, the following are recommended:

- Reduce the road network density in commercial forestry and ensure acceptable standards are maintained, meeting both economic and environmental requirements;
- Minimise the impact of stream crossings by improved road drain age and a means of preventing or minimising sediment input into the river. Ensure that culverts at crossings are large enough to allow free flow of water to prevent deposition above the crossing;
- Improve road drainage to ensure that water does not run from the road directly into streams. Roads that run parallel to rivers and streams should be maintained as grassed roads;
- Maintain natural vegetation buffer zones along water courses. These will serve as filter strips to improve water quality in the catchment. Riparian zones are effective in filtering sediments, nutrients and other pollutants from overland flow.

7.1.2 Uncontrolled Fires

The loss of soil after uncontrolled fires in commercial forestry areas are extreme, with severe negative consequences to productive land and receiving riverine ecosystems. There has been an exponential increase in the hectares of uncontrolled forest fires since the 1970's (Olivier 2009), pa rtially linked to an increase extreme weather events (e.g. droughts and floods).

Erosion control after uncontrolled fires is paramount after uncontrolled forest fires, and land-users should provide detailed plans to the ICMA. These erosion control plans must indicate:

- How soil loss from burnt compartments will be prevented;
- The upgrade of road drainage and stream crossings in affected areas to ensure they can cope with increased run-off (absence of vege tation to filter surface flow), and;
- How they will monitor soil loss from the land surface and the sedimentation inputs into rivers and streams.

7.1.3 Control Legal and Illegal Mining

There are several mines which are operated both legally and illegally. At the legal mine close to the Rietfontein Mine site (USM 14), sediments from a tributary are entering the Sabie River. Illegal mining are sporadic, and appears and disappears often at the same spots. The illegal mining mostly involves gold panning, which takes place in or on the edge of streams, severely altering the instream habitat and riparian zones. The following is recommended:

Legal Mining: Regular inspections to ensure requirements stipulated in the water license and Environmental Impact Assessment are adhered to. Non-conformity should be dealt with sooner rather than later.
Illegal Mining: Initiate a link with authorities (e.g. SA Police, Department of Water and Environmental Affairs, State Prosecutor and Magistrate, Inkomati Catchment Management Agency) and land-users (e.g. Komatiland Forests, York Timbe rs) to ensure reported cases are immediately dealt with and follow up visits (e.g. forest guards) to these areas are scheduled.

7.2 WATER QUALITY

There are several sources in the catchment responsible for the deterioration water quality in the upper Sabie catchment. Excessive sediment inputs from commercial forestry and mining has been dealt with. Other sources are high organic matter inputs from forest-shrub dominated riparian zones, sawmill waste, hand-f ed trout dams, villages, Sabie, Simile and Graskop Towns, and sewage works.

7.2.1 Maintain Riparian Buffer Zones

The maintenance of riparian buffer zones are a legal requirement and should be enforced.

7.2.1.1 Declared Alien Invading Plants

Declared weeds and invader plants covered by the Conservation of Agricultural Resources Act (CARA, Act 43 of 1983) are subject to the following:

Category 1: Declared and prohibited weed plants. These plants are detrimental to the environment (e.g. threatens biodiversity, high water use, replace indigenous vegetation, etc.) and to humans (directly and indirectly). The presence of plants in this category are prohibited on any land or water surface area in South Africa, and must be controlled and eradicated, with the exception of those in biological control reserves. Examples of plants commonly encountered in commercial forestry areas that falls within this category are *Caesalpinia decapetala* (Mauritius Thorn), *Lantana camara*, and *Solanum mauritianum* (Bugweed).
Category 2: Plants declared as invaders, but they have commercial or utility value. Useful qualities include for example timber production, woodlots, animal fodder, and soil stabilisation. Plants in this category are allowed in demarcated areas under controlled conditions (e.g. commercial tree compartment), but are prohibited within 30 m of the 1:50 year floodline of watercourses or wetlands. Examples of plants in this category include *Acacia mearnsii*, *Eucalyptus grandis*, *Pinus patula*, *Salix babylonica*, etc.

Category 3: Invasive ornamental plants. No further trading or planting is allowed. Existing plants may remain, but those within 30 m of the 1:50 year floodline of watercourses or wetlands must be eradicated. Examples of plants regularly recorded in commercial forestry areas in this category include *Ligustrum japonicum* (Japanese Privet), *Lilium formosanum* (St Joseph's Lily), *Morus alba* (White Mulberry), *Jacaranda mimosifolia* (Jacaranda), etc.

7.2.1.2 Activities within riparian zones

The National Water Act (NWA, Act 36 of 1998) specifies in Section 21(a-k) all of the water uses than needs to be regulated.

Any activity within the 1 in 100 year flood line or riparian habitat, whichever is the greatest or within a 500 m radius from the boundary of a wetland, needs to be authorized through a Water Use License. An examples is Miracle Timbers Sawmill which is located on the banks of the Sabie River upstream fr om the Sabieshoek site. All their sawmill waste is dumped next to the river

Ensure activities in riparian zones are licensed, controlled and monitored.

7.2.2 Waste and Storm-water Management at Sawmills

Seven sawmills are operational in the Upper Sabie Catchment, three in Sabie, two in the Spitskopspruit sub-catchment, and two near Graskop in the Mac-Mac sub-catchment. Of these, only York Timber's sawmills in Sabie and Graskop are operating with integrated management plans which considers the water resource. The other mills are characterized by a high build-up of organic waste (e.g. sawdust, bark & off-cuts), and extremely poor management of storm-water run-off. Most of these mills are located in the riparian zones of the catchments they are located in.

- Chemical monitoring results as required by the Water Use License's should be reported to authorities (e.g. DWEA & ICMA). Data collected should be captured and analysed to determine trends.
- All sawmills should provide plans which deals with how they manage their waste, as well as effluent and storm-water run-off, and;
- Protect and manage riparian zones on their property, with the purpose of maintain the filtering capacity these zones provide.

7.2.3 Sewage and polluted storm-water from Sabie and Graskop Municipalities

Raw sewage entering the Sabie, Klein Sabie and Mac-Mac Rivers through poor management of sewage drainage systems in municipal areas. There are regu lar incidents of overflowing blocked drains, with raw sewage flowing into storm-water drains that pours directly into receiving rivers.

- Municipal areas should provide a register in which the dates and location of the reported blocked sewage drain are noted, actions taken and the date the blockage was removed. This will ensure these blocked drains are not overflowing for weeks on end before its dealt with;
- Sewage drains out of public view (e.g. along the Klein Sabie River) should be visited weekly to ensure they are functioning;

The chemical results from Sewage Waste Water Treatment Works should be reported to authorities (e.g. DWEA & ICMA). Data collected should be captured and analysed to determine trends, and;

Storm-water management plans should be implemented in municipal areas, in order to ensure polluted water does not enter natural water resources.

7.2.4 Nutrient rich waters from Trout-fed Dams

Reared trout are fed artificially in dams located in the upper Sabie River. The effluent flowing from these dams should be monitored and the results reported to authorities (e.g. DWEA & ICMA). Data collected should be captured and analysed to determine trends.

7.2.5 High organic inputs from forest-shrub dominated riparian zones

The exclusion of fire from riparian zones, and the shading of these zones by commercial forestry has changed grass-shrub dominated riparian areas to forest-shrub dominated. The leaf litter input into these streams have therefore increased compared to those under natural conditions (grass-shrub dominated). The shading will also affect water temperature.

Riparian zones should be managed to maintain natural vegetation (structural and composition), and;

Water temperature data loggers should be installed at selected points in the main rivers and streams to collect data on long term changes.

7.2.6 Chemical Data from Gauging Stations

Monthly long-term chemistry data are collected from gauging stations along most of the main rivers in the country. This chemical information should be captured electronically and interpreted by specialists in the chemical ecology of aquatic ecosystems. Long term trends in chemical data collected from the Sabie and Klein Sabie Rivers indicate considerable changes over time in water quality, with some changes subtle and others more substantial.

7.3 TROUT STOCKING

The river above Sabie Falls are regularly stocked with exotic trout species, without a clear understanding of the consequences. This regular stocking takes place despite the fact that the stocked rainbow trout, *Oncorhynchus mykiss*, have been declared world-wide as one of the world's 100 worst invaders (Lowe et al. 2000).

Detailed monitoring and study of the distribution and requirements of indigenous fish species in the Upper Sabie River (above the Sabie Falls), to ensure their survival and ecological role in the system is not jeopardised;

Interpret data [7] from stocking rates (permit requirements) and detailed fish monitoring to continuously determine changes and threats to indigenous fish populations and in turn the integrity of the system;

[7]The purpose of monitoring is to keep a finger on the pulse, and the interpretation of data (especially long-term monitoring data) is crucial to this concept. Through interpretation of data, problems can be identified, and management intervention initiated timeously. If not, the purpose of monitoring is only to provide sheltered employment.

Identify refugia and ensure the maintenance and protection of these areas;
Both locals and personal observations suggests fewer sightings of *Varicorhinus nelspruitensis* (Incomati Chissel-mouth), an indigenous species previously commonly seen in schools twisting and turning in the clear runs along the upper Sabie River. The decline in the abundance of this species needs to be quantified. Declines can be linked to a combination of water quality, predation from exotic fish, changes in trophic-cascades and habitat.

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APPENDIX A

Photos per Sampling Point

APPENDIX A: Photos of Sampling Points

USM 1 – Sabie River @ Aand-de-Vliet

CO-ORDINATES (dd mm ss.s)	**ELEVATION RANGE (m a.s.l.)**
25° 01' 42.9" S & 31° 03' 14.1" E	480 – 500
High Flow – February 2013	

Figure A-1: Upstream view of the Sabie River at Aand-de-Vliet (USM 01), taken on 06 February 2013 (G Diedericks).

Figure A-2: Downstream view of the Sabie River at Aand-de-Vliet (USM 01), taken on 06 February 2013 (G Diedericks).

USM 01: Sabie River @ Aand-de-Vliet

CO-ORDINATES (dd mm ss.s)	**ELEVATION RANGE (m a.s.l.)**
25° 01' 42.9" S & 31° 03' 14.1" E	480 – 500
Low Flow – September 2013	

Figure A-3: Upstream view of the Sabie River at Aand-de-Vliet (USM 01), taken on 18 September 2013 (G Diedericks).

Figure A-4: Downstream view of the Sabie River at Aand-de-Vliet (USM 01), taken on 18 September 2013 (G Diedericks).

USM 2 – Sabie River @ Brandwag

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 01' 48.3" S & 31° 01' 31.3" E	500 - 520
High Flow – February 2013	

Figure A-5: Upstream view of the Sabie River at the Mac Mac/Sabaan confluence (Brandwag – USM 02), taken on 06 February 2013 (G Diedericks).

Figure A-6: Downstream view of the Sabie River at the Mac Mac/Sabaan confluence (Brandwag – USM 02), taken on 06 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 01' 48.3" S & 31° 01' 31.3" E	500 - 520
Low Flow – September 2013	

Figure A-5: Upstream view of the Sabie River at the Mac-Mac/Sabaan confluence (Brandwag – USM 02), taken on 18 September 2013 (G Diedericks).

Figure A-6: Downstream view of the Sabie River at the Mac-Mac/Sabaan confluence (Brandwag – USM 02), taken on 18 September 2013 (G Diedericks).

USM 3 – Mac-Mac River @ Brandwag

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 01' 46.6" S & 31° 01' 32.1" E	500 - 520
High Flow – February 2013	
	
Figure A-7: Upstream view of the Mac-Mac River at Brandwag (USM 03), taken on 06 February 2013 (G Diedericks).	**Figure A-8:** Downstream view of the Mac-Mac River at Brandwag (USM 02), taken on 06 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 01' 46.6" S & 31° 01' 32.1" E	500 - 520
Low Flow – February 2013	
	
Figure A-9: Upstream view of the Mac-Mac River at Brandwag (USM 03), taken on 18 September 2013 (G Diedericks).	**Figure A-10:** Downstream view of the Mac-Mac River at Brandwag (USM 03), taken on 18 September 2013 (G Diedericks).

USM 4 – Sabaan River @ Brandwag

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 01' 49.5" S & 31° 01' 29.8" E	500 - 520

High Flow – February 2013

Figure A-11: Upstream view of the Sabaan River at Brandwag (USM 04), taken on 06 February 2013 (G Diedericks).

Figure A-12: Downstream view of the Sabaan River at Brandwag (USM 04), taken on 06 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 01' 49.5" S & 31° 01' 29.8" E	500 - 520

Low Flow – September 2013

Figure A-13: Upstream view of the Sabaan River at Brandwag (USM 04), taken on 18 September 2013 (G Diedericks).

Figure A-14: Downstream view of the Sabaan River at Brandwag (USM 04), taken on 18 September 2013 (G Diedericks).

USM 5 – Buffelspruit @ Vergenoeg

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 03' 24.0" S & 30° 56' 04.2" E	760 - 780
High Flow – February 2013	

Figure A-15: Upstream view of the Buffelspruit at Vergenoeg (USM 05), taken on 06 February 2013 (G Diedericks).

Figure A-16: Downstream view of the Buffelspruit at Vergenoeg (USM 05), taken on 06 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 03' 24.0" S & 30° 56' 04.2" E	760 - 780
Low Flow – September 2013	

Figure A-17: Upstream view of the Buffelspruit at Vergenoeg (USM 05), taken on 18 September 2013 (G Diedericks).

Figure A-18: Downstream view of the Buffelspruit at Vergenoeg (USM 05), taken on 18 September 2013 (G Diedericks).

USM 6 – Sabie River @ Lunsklip

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 02' 54.2" S & 30° 55' 51.6" E	720 - 740
High Flow – February 2013	
 Figure A-19: Upstream view of the Sabie River at Lunsklip (USM 06), taken on 06 February 2013 (G Diedericks).	 Figure A-20: Downstream view of the Sabie River at Lunsklip (USM 06), taken on 06 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 02' 54.2" S & 30° 55' 51.6" E	720 - 740
Low Flow – September 2013	
 Figure A-21: Upstream view of the Sabie River at Lunsklip (USM 06), taken on 18 September 2013 (G Diedericks).	 Figure A-22: Downstream view of the Sabie River at Lunsklip (USM 06), taken on 18 September 2013 (G Diedericks).

USM 7 – KaMahukwane

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 02' 26.6" S & 30° 55' 20.1" E	760 - 780

High Flow – February 2013

Figure A-23: Upstream view of the KaMahukwane (USM 07), taken on 06 February 2013 (G Diedericks).

Figure A-24: Downstream view of the KaMahukwane (USM 07), taken on 06 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 02' 26.6" S & 30° 55' 20.1" E	760 - 780

Low Flow – September 2013

Figure A-25: Upstream view of the KaMahukwane (USM 07), taken on 18 September 2013 (G Diedericks).

Figure A-26: Downstream view of the KaMahukwane (USM 07), taken on 18 September 2013 (G Diedericks).

USM 8 – Sabie River @ Frankfort Bridge

USM 08: Sabie River @ Frankfort Bridge	
CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 03' 45.2" S & 30° 54' 28.6" E	780 - 800
High Flow – February 2013	

Figure A-27: Upstream view of the Sabie River at Frankfort Bridge (USM 08), taken on 06 February 2013 (G Diedericks).

Figure A-28: Downstream view of the Sabie River @ Frankfort Bridge (USM 08), taken on 06 February 2013 (G Diedericks).

USM 9 - Goudstroom

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 04' 14.6" S & 30° 54' 04.7" E	800 - 820
High Flow – February 2013	

Figure A-29: Upstream view of the Goudstroom (USM 09), taken on 06 February 2013 (G Diedericks).

Figure A-30: Downstream view of the Goudstroom (USM 09), taken on 06 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 04' 14.6" S & 30° 54' 04.7" E	800 - 820
Low Flow – September 2013	

Figure A-31: Upstream view of the Goudstroom (USM 09), taken on 18 September 2013 (G Diedericks).

Figure A-32: Downstream view of the Goudstroom (USM 09), taken on 18 September 2013 (G Diedericks).

USM 10 – Sabie River @ DR de Wet

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 03' 35.6" S & 30° 53' 19.4" E	780 - 800
High Flow – February 2013	

Figure A-33: Upstream view of the Sabie River below DR de Wet (USM 10), taken on 06 February 2013 (G Diedericks).

Figure A-34: Downstream view of the Sabie River below DR de Wet (USM 10), taken on 06 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
S -25.06027 & E 30.88765	790 - 810
Low Flow – September 2013	

Figure A-35: Upstream view of the Sabie River below DR de Wet (USM 10), taken on 18 September 2013 (G Diedericks).

Figure A-36: Downstream view of the Sabie River below DR de Wet (USM 10), taken on 18 September 2013 (G Diedericks).

USM 11 – DR de Wet

USM 11: DR de Wet	
CO-ORDINATES (dd mm ss.s)	**ELEVATION RANGE (m a.s.l.)**
25° 03' 27.9" S & 30° 52' 40.3" E	820 - 840
High Flow – February 2013	
	
Figure A-37: Upstream view of the DR de Wet stream (USM 11), taken on 07 February 2013 (G Diedericks).	**Figure A-38:** Downstream view of the DR de Wet stream (USM 11), taken on 07 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	**ELEVATION RANGE (m a.s.l.)**
25° 03' 27.9" S & 30° 52' 40.3" E	820 - 840
Low Flow – September 2013	
	
Figure A-39: Upstream view of the DR de Wet stream (USM 11), taken on 18 September 2013 (G Diedericks).	**Figure A-40:** Downstream view of the DR de Wet stream (USM 11), taken on 18 September 2013 (G Diedericks).

USM 12 - Malieveldspruit

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 04' 45.1" S & 30° 50' 48.9" E	920 - 940
High Flow – February 2013	

Figure A-41: Upstream view of the Malieveldspruit (USM 12), taken on 07 February 2013 (G Diedericks).

Figure A-42: Downstream view of the Malieveldspruit (USM 12), taken on 07 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 04' 45.1" S & 30° 50' 48.9" E	920 - 940
Low Flow – September 2013	

Figure A-43: Upstream view of the Malieveldspruit (USM 12), taken on 18 September 2013 (G Diedericks).

Figure A-44: Downstream view of the Malieveldspruit (USM 12), taken on 18 September 2013 (G Diedericks).

USM 13 – Coopers Creek

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 04' 43.1" S & 30° 49' 37.5" E	900 - 920
High Flow – February 2013	

Figure A-45: Upstream view of the Coopers Creek (USM 13), taken on 07 February 2013 (G Diedericks).

Figure A-46: Downstream view of the Coopers Creek (USM 13), taken on 07 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 04' 43.1" S & 30° 49' 37.5" E	900 - 920
Low Flow – September 2013	

Figure A-47: Upstream view of the Coopers Creek (USM 13), taken on 18 September 2013 (G Diedericks).

Figure A-48: Downstream view of the Coopers Creek (USM 13), taken on 18 September 2013 (G Diedericks).

USM 14 – Sabie River @ Rietfontein Mine

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 04' 44.8" S & 30° 49' 34.7" E	900 - 920
High Flow – February 2013	

Figure A-49: Upstream view of the Sabie River below Rietfontein Mine (USM 14), taken on 07 February 2013 (G Diedericks).

Figure A-50: Downstream view of the Sabie River below Rietfontein Mine (USM 14), taken on 07 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 04' 44.8" S & 30° 49' 34.7" E	900 - 920
Low Flow – September 2013	

Figure A-51: Upstream view of the Sabie River below Rietfontein Mine (USM 14), taken on 18 September 2013 (G Diedericks).

Figure A-52: Downstream view of the Sabie River below Rietfontein Mine (USM 14), taken on 18 September 2013 (G Diedericks).

USM 15 – Sabie River above Rietfontein Mine

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 05' 32.8" S & 30° 48' 48.3" E	920 - 940
High Flow – February 2013	

Figure A-53: Upstream view of the Sabie River above Rietfontein Mine (USM 15), taken on 07 February 2013 (G Diedericks).

Figure A-54: Downstream view of the Sabie River above Rietfontein Mine (USM 15), taken on 07 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 05' 32.8" S & 30° 48' 48.3" E	920 - 940
Low Flow – September 2013	

Figure A-55: Upstream view of the Sabie River above Rietfontein Mine (USM 15), taken on 18 September 2013 (G Diedericks).

Figure A-56: Downstream view of the Sabie River above Rietfontein Mine (USM 15), taken on 18 September 2013 (G Diedericks).

USM 16 - Spitskopspruit

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 05' 42.7" S & 30° 48' 19.9" E	940 - 960
High Flow – February 2013	

Figure A-57: Upstream view of the Spitskopspruit (USM 16), taken on 07 February 2013 (G Diedericks).

Figure A-58: Downstream view of the Spitskopspruit (USM 16), taken on 07 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 05' 42.7" S & 30° 48' 19.9" E	940 - 960
Low Flow – September 2013	

Figure A-59: Upstream view of the Spitskopspruit (USM 16), taken on 18 September 2013 (G Diedericks).

Figure A-60: Downstream view of the Spitskopspruit (USM 16), taken on 18 September 2013 (G Diedericks).

USM 17: Sabie River below Sabie Sewage Farm

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 05' 29.2" S & 30° 47' 41.7" E	940 - 960

High Flow – February 2013

Figure A-61: Upstream view of the Sabie River below the Sabie Sewage Farm (USM 17), taken on 07 February 2013 (G Diedericks).

Figure A-62: Downstream view of the Sabie River below the Sabie Sewage Farm (USM 17), taken on 07 February 2013 (G Diedericks).

USM 18 – Klein Sabie River

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 05' 16.8" S & 30° 46' 42.1" E	980 - 1000

High Flow – February 2013

Figure A-63: Upstream view of the Klein Sabie River (USM 18), taken on 07 February 2013 (G Diedericks).

Figure A-64: Downstream view of the Klein Sabie River (USM 18), taken on 07 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 05' 16.8" S & 30° 46' 42.1" E	980 - 1000

Low Flow – September 2013

Figure A-65: Upstream view of the Klein Sabie River (USM 18), taken on 18 September 2013 (G Diedericks).

Figure A-66: Downstream view of the Klein Sabie River (USM 18), taken on 18 September 2013 (G Diedericks).

USM 19 - Vertroostings

CO-ORDINATES (dd mm ss.s)	**ELEVATION RANGE (m a.s.l.)**
25° 05' 36.9" S & 30° 46' 15.7" E	980 - 1000
High Flow – February 2013	
	
Figure A-67: Upstream view of the Vertroostings (USM 19), taken on 07 February 2013 (G Diedericks).	**Figure A-68:** Downstream view of the Vertroostings (USM 19), taken on 07 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	**ELEVATION RANGE (m a.s.l.)**
25° 05' 36.9" S & 30° 46' 15.7" E	980 - 1000
Low Flow – September 2013	
	
Figure A-69: Upstream view of the Vertroostings (USM 19), taken on 18 September 2013 (G Diedericks).	**Figure A-70:** Downstream view of the Vertroostings (USM 19), taken on 18 September 2013 (G Diedericks).

USM 20 – Sabie River below York Sawmill

CO-ORDINATES (dd mm ss.s)	**ELEVATION RANGE (m a.s.l.)**
25° 05' 54.4" S & 30° 45' 16.4" E	1000 - 1020
High Flow – February 2013	

Figure A-71: Upstream view of the Sabie River below York Sawmill (USM 20), taken on 07 February 2013 (G Diedericks).

Figure A-72: Downstream view of the Sabie River below York Sawmill (USM 20), taken on 07 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	**ELEVATION RANGE (m a.s.l.)**
25° 05' 54.4" S & 30° 45' 16.4" E	1000 - 1020
Low Flow – September 2013	

Figure A-73: Upstream view of the Sabie River below York Sawmill (USM 20), taken on 18 September 2013 (G Diedericks).

Figure A-74: Downstream view of the Sabie River below York Sawmill (USM 20), taken on 18 September 2013 (G Diedericks).

USM 21 – Bridal Veil

CO-ORDINATES (dd mm ss.s)	**ELEVATION RANGE (m a.s.l.)**
25° 05' 48.4" S & 30° 44' 53.7" E	1020 - 1040
High Flow – February 2013	
	
Figure A-75: Upstream view of the Bridal Veil stream (USM 21), taken on 07 February 2013 (G Diedericks).	**Figure A-76:** Downstream view of the Bridal Veil stream (USM 21), taken on 07 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	**ELEVATION RANGE (m a.s.l.)**
25° 05' 48.4" S & 30° 44' 53.7" E	1020 - 1040
Low Flow – September 2013	
	
Figure A-77: Upstream view of the Bridal Veil stream (USM 21), taken on 18 September 2013 (G Diedericks).	**Figure A-78:** Downstream view of the Bridal Veil stream (USM 21), taken on 18 September 2013 (G Diedericks).

USM 22 – Sabie River above York Sawmill

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 06' 25.7" S & 30° 44' 41.2" E	1020 - 1040
High Flow – February 2013	

Figure A-79: Upstream view of the Sabie River above York Sawmill (USM 22), taken on 07 February 2013 (G Diedericks).

Figure A-80: Downstream view of the Sabie River above York Sawmill (USM 22), taken on 07 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 06' 25.7" S & 30° 44' 41.2" E	1020 - 1040
Low Flow – September 2013	

Figure A-81: Upstream view of the Sabie River above York Sawmill (USM 22), taken on 18 September 2013 (G Diedericks).

Figure A-82: Downstream view of the Sabie River above York Sawmill (USM 22), taken on 18 September 2013 (G Diedericks).

USM 23 - Manyeleti

CO-ORDINATES (dd mm ss.s)	**ELEVATION RANGE (m a.s.l.)**
25° 07' 02.1" S & 30° 43' 56.2" E	1040 - 1060
High Flow – February 2013	

Figure A-83: Upstream view of the Manyeleti (USM 23), taken on 07 February 2013 (G Diedericks).

Figure A-84: Downstream view of the Manyeleti (USM 23), taken on 07 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	**ELEVATION RANGE (m a.s.l.)**
25° 07' 02.1" S & 30° 43' 56.2" E	1040 - 1060
Low Flow – September 2013	

Figure A-85: Upstream view of the Manyeleti (USM 23), taken on 18 September 2013 (G Diedericks).

Figure A-86: Downstream view of the Manyeleti (USM 23), taken on 18 September 2013 (G Diedericks).

USM 24 – Lone Creek

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 07' 04.5" S & 30° 43' 26.4" E	1040 - 1060
High Flow – February 2013	
	
Figure A-87: Upstream view of the Lone Creek (USM 24), taken on 07 February 2013 (G Diedericks).	**Figure A-88:** Downstream view of the Lone Creek (USM 25), taken on 07 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 07' 04.5" S & 30° 43' 26.4" E	1040 - 1060
Low Flow – September 2013	
	
Figure A-89: Upstream view of the Lone Creek (USM 24), taken on 18 September 2013 (G Diedericks).	**Figure A-90:** Downstream view of the Lone Creek (USM 24), taken on 18 September 2013 (G Diedericks).

USM 25 – Sabie River @ Sabieshoek

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 07' 15.2" S & 30° 43' 01.3" E	1060 - 1080
High Flow – February 2013	

Figure A-91: Upstream view of the Sabie River at Sabieshoek (USM 25), taken on 07 February 2013 (G Diedericks).

Figure A-92: Downstream view of the Sabie River at Sabieshoek (USM 25), taken on 07 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 07' 15.2" S & 30° 43' 01.3" E	1060 - 1080
Low Flow – September 2013	

Figure A-93: Upstream view of the Sabie River at Sabieshoek (USM 25), taken on 18 September 2013 (G Diedericks).

Figure A-94: Downstream view of the Sabie River at Sabieshoek (USM 25), taken on 18 September 2013 (G Diedericks).

USM 26 – Sabie River below Horseshoe Falls

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 07' 41.4" S & 30° 41' 56.0" E	1100 - 1120
High Flow – February 2013	

Figure A-95: Upstream view of the Sabie River below Horseshoe Falls (USM 26), taken on 08 February 2013 (G Diedericks).

Figure A-96: Downstream view of the Sabie River below Horseshoe Falls (USM 26), taken on 08 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 07' 41.4" S & 30° 41' 56.0" E	1100 - 1120
Low Flow – September 2013	

Figure A-97: Upstream view of the Sabie River below Horseshoe Falls (USM 26), taken on 18 September 2013 (G Diedericks).

Figure A-98: Downstream view of the Sabie River below Horseshoe Falls (USM 26), taken on 18 September 2013 (G Diedericks).

USM 27 – Weber's Spruit

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 07' 45.7" S & 30° 41' 50.6" E	1100 - 1120
High Flow – February 2013	

Figure A-99: Upstream view of the Weber's Spruit (USM 27), taken on 08 February 2013 (G Diedericks).

Figure A-100: Downstream view of the Weber's Spruit (USM 27), taken on 08 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 07' 45.7" S & 30° 41' 50.6" E	1100 - 1120
Low Flow – September 2013	

Figure A-101: Upstream view of the Weber's Spruit (USM 27), taken on 18 September 2013 (G Diedericks).

Figure A-102: Downstream view of the Weber's Spruit (USM 27), taken on 18 September 2013 (G Diedericks).

USM 28 – Sabie River above Horseshoe Falls

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 08' 10.0" S & 30° 41' 02.2" E	1160 - 1180
High Flow – February 2013	

Figure A-103: Upstream view of the Sabie River above Horseshoe Falls (USM 28), taken on 08 February 2013 (G Diedericks).

Figure A-104: Downstream view of the Sabie River above Horseshoe Falls (USM 28), taken on 08 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 08' 10.0" S & 30° 41' 02.2" E	1160 - 1180
Low Flow – September 2013	

Figure A-105: Upstream view of the Sabie River above Horseshoe Falls (USM 28), taken on 18 September 2013 (G Diedericks).

Figure A-106: Downstream view of the Sabie River above Horseshoe Falls (USM 28), taken on 18 September 2013 (G Diedericks).

USM 29 - Jantjiesbos

CO-ORDINATES (dd mm ss.s)	**ELEVATION RANGE (m a.s.l.)**
25° 08' 25.0" S & 30° 40' 31.7" E	1200 - 1220
High Flow – February 2013	

Figure A-107: Upstream view of the Jantjiesbos (USM 29), taken on 08 February 2013 (G Diedericks).

Figure A-108: Downstream view of the Jantjiesbos (USM 29), taken on 08 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	**ELEVATION RANGE (m a.s.l.)**
25° 08' 25.0" S & 30° 40' 31.7" E	1200 - 1220
Low Flow – September 2013	

Figure A-107: Upstream view of the Jantjiesbos (USM 29), taken on 18 September 2013 (G Diedericks).

Figure A-108: Downstream view of the Jantjiesbos (USM 29), taken on 18 September 2013 (G Diedericks).

USM 30 – Sabie River @ Long Tom

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 08' 39.6" S & 30° 40' 15.6" E	1220 - 1240
High Flow – February 2013	

Figure A-109: Upstream view of the Sabie River below Long Tom (USM 30), taken on 08 February 2013 (G Diedericks).

Figure A-110: Downstream view of the Sabie River below Long Tom (USM 30), taken on 08 February 2013 (G Diedericks).

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 08' 39.6" S & 30° 40' 15.6" E	1220 - 1240
Low Flow – September 2013	

Figure A-111: Upstream view of the Sabie River below Long Tom (USM 30), taken on 18 September 2013 (G Diedericks).

Figure A-112: Downstream view of the Sabie River below Long Tom (USM 30), taken on 18 September 2013 (G Diedericks).

USM 31 – Sabie River @ Headwaters

CO-ORDINATES (dd mm ss.s)	ELEVATION RANGE (m a.s.l.)
25° 08' 20.4" S & 30° 38' 05.2" E	1760 - 1780
Low Flow – September 2013	
	
Figure A-113: Upstream view of the Sabie River at Headwaters (USM 31), taken on 18 September 2013 (G Diedericks).	**Figure A-114:** Downstream view of the Sabie River at Headwaters (USM 31), taken on 18 September 2013 (G Diedericks).

APPENDIX B

Lab Results Sediment Samples

Test Report

Environmental Biomonitoring Services
Postnet Suite 225, P/Bag X9910
White River
1240

Samples Received: 2013/09/19
Sampled by: Unknown
Report # : 14-08251
Order #: None
Acc # : M99-334

Telephone: 082 337 2312
Fax:
E-mail: gerhardd@mweb.co.za

Sample(s) received: 6 x Sediment sample(s)
Sample condition: Average - Plastic Bag
Sub-contractor: None

LAB No.		14-08251	14-08252	14-08253	14-08254	14-08255	14-08256
Your Reference		1	2	3	4	5	6
Particle Size							
>2.0mm	%	2.94	3.67	18.06	39.35	1.96	30.33
1.4-2.0mm	%	4.08	5.18	10.74	18.85	6.91	15.94
600 µm-1.4mm	%	32.84	66.08	51.85	31.72	26.5	19.82
355-600 µm	%	31.3	17.38	14.97	6.17	31.14	15.26
212-355 µm	%	23.93	5.62	3.34	2.59	21.48	7.47
38-212 µm	%	4.22	1.73	0.78	0.98	11.26	9.69
<38 µm	%	0.69	0.34	0.26	0.34	0.75	1.49

L.K. Auerswald B.Sc. Agric (Hons) (Technical Manager)
W. Marais (Head of Laboratory)

Date: 2013/10/08

Test Report

Environmental Biomonitoring Services
Postnet Suite 225, P/Bag X9910
White River
1240

Samples Received: 2013/09/19
Sampled by: Unknown
Report # : 14-08257
Order #: None
Acc # : M99-334

Telephone: 082 337 2312
Fax:
E-mail: gerhardd@mweb.co.za

Sample(s) received: 6 x Sediment sample(s)
Sample condition: Average - Plastic Bag
Sub-contractor: None

LAB No.		14-08257	14-08258	14-08259	14-08260	14-08261	14-08262
Your Reference		7	8	9	10	11	12
Particle Size							
>2.0mm	%	5.31	11.95	0.05	4.96	3.68	0.65
1.4-2.0mm	%	8.09	11.93	1.01	9.83	2.67	4.02
600 µm-1.4mm	%	35.57	31.44	13.87	53.46	20.18	69.96
355-600 µm	%	34.49	24.69	50.82	24.16	20.27	22.09
212-355 µm	%	12.50	14.00	28.14	5.59	24.80	2.72
38-212 µm	%	3.7	5.39	5.74	1.51	26.77	0.41
<38 µm	%	0.34	0.60	0.37	0.49	1.54	0.15

L.K. Auerswald B.Sc. Agric (Hons) (Technical Manager)
W. Marais (Head of Laboratory)

Date: 2013/10/08

Labserve Analytical Services
Nebo Park, Suikerriet Str, Nelspruit
Telephone : +27 (13) 752 4745
Facsimile : +27 (13) 752 4617
P.O. Box 1920, Nelspruit, 1200
E-mail: info@labserve.net
www.labserve.net

Test Report

Environmental Biomonitoring Services
Postnet Suite 225, P/Bag X9910
White River
1240

Samples Received: 2013/09/19
Sampled by: Unknown
Report # : 14-08263
Order #: None
Acc # : M99-334

Telephone: 082 337 2312
Fax:
E-mail: gerhardd@mweb.co.za

Sample(s) received: 6 x Sediment sample(s)
Sample condition: Average - Plastic Bag
Sub-contractor: None

LAB No.		14-08263	14-08264	14-08265	14-08266	14-08267	14-08268
Your Reference		13	14	15	16	17	18
Particle Size							
>2.0mm	%	13.97	14.03	1.90	18.46	9.15	8.83
1.4-2.0mm	%	14.58	21.12	2.86	8.87	13.10	3.60
600 µm-1.4mm	%	35.35	40.18	39.59	32.25	36.55	7.54
355-600 µm	%	20.27	14.62	30.69	20.84	24.57	9.05
212-355 µm	%	12.42	5.63	14.50	11.86	10.53	18.55
38-212 µm	%	3.06	3.85	9.77	6.95	5.59	49.42
<38 µm	%	0.35	0.57	0.69	0.77	0.51	3.01

L.K. Auerswald B.Sc. Agric (Hons) (Technical Manager) Date: 2013/10/08
W. Marais (Head of Laboratory)

Labserve Analytical Services
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A member & participant of the SABS Water-Check Scheme, the National Laboratory Association's Microbiology Scheme, and Agrilasa's Interlaboratory Control Scheme

Test Report

Environmental Biomonitoring Services
Postnet Suite 225, P/Bag X9910
White River
1240

Samples Received: 2013/09/19
Sampled by: Unknown
Report # : 14-08269
Order #: None
Acc # : M99-334

Telephone: 082 337 2312
Fax:
E-mail: gerhardd@mweb.co.za

Sample(s) received: 6 x Sediment sample(s)
Sample condition: Average - Plastic Bag
Sub-contractor: None

LAB No.		14-08269	14-08270	14-08271	14-08272	14-08273	14-08274
Your Reference		19	20	21	22	23	24
Particle Size							
>2.0mm	%	52.31	21.94	22.86	20.43	32.26	42.60
1.4-2.0mm	%	17.35	13.08	13.16	9.40	12.87	13.18
600 µm-1.4mm	%	18.19	18.46	29.19	25.18	20.6	16.74
355-600 µm	%	4.79	11.07	16.91	20.91	11.33	7.92
212-355 µm	%	2.29	9.14	7.23	11.27	8.19	6.14
38-212 µm	%	3.55	22.08	8.82	10.93	12.87	11.84
<38 µm	%	1.52	4.23	1.83	1.88	1.88	1.58

L.K. Auerswald B.Sc. Agric (Hons) (Technical Manager)
W. Marais (Head of Laboratory)

Date: 2013/10/08

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www.labserve.net

Test Report

Environmental Biomonitoring Services
Postnet Suite 225, P/Bag X9910
White River
1240

Samples Received: 2013/09/19
Sampled by: Unknown
Report # : 14-08275
Order #: None
Acc # : M99-334

Telephone: 082 337 2312
Fax:
E-mail: gerhardd@mweb.co.za

Sample(s) received: 6 x Sediment sample(s)
Sample condition: Average - Plastic Bag
Sub-contractor: None

LAB No.		14-08275	14-08276	14-08277	14-08278	14-08279	14-08280
Your Reference		25	26	27	28	29	30
Particle Size							
>2.0mm	%	6.00	32.48	46.04	26.04	6.07	46.52
1.4-2.0mm	%	10.78	18.84	16.18	14.12	7.46	16.36
600 µm-1.4mm	%	27.14	19.06	16.62	23.19	21.74	14.6
355-600 µm	%	22.32	9.34	7.00	13.4	24.52	7.42
212-355 µm	%	12.30	7.76	5.00	9.19	20.48	5.38
38-212 µm	%	18.73	11.08	6.92	12.06	18.48	7.6
<38 µm	%	2.73	1.44	2.24	2.00	1.25	2.12

L.K. Auerswald B.Sc. Agric (Hons) (Technical Manager) Date: 2013/10/08
W. Marais (Head of Laboratory)

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www.labserve.net

Test Report

Environmental Biomonitoring Services
Postnet Suite 225, P/Bag X9910
White River
1240

Samples Received: 2013/09/19
Sampled by: Unknown
Report # : 14-08281
Order #: None
Acc # : M99-334

Telephone: 082 337 2312
Fax:
E-mail: gerhardd@mweb.co.za

Sample(s) received: 1 x Sediment sample(s)
Sample condition: Average - Plastic Bag
Sub-contractor: None

LAB No.		14-08281
Your Reference		31
Particle Size		
>2.0mm	%	39.23
1.4-2.0mm	%	22.11
600 µm-1.4mm	%	26.59
355-600 µm	%	8.24
212-355 µm	%	2.03
38-212 µm	%	1.22
<38 µm	%	0.58

L.K. Auerswald B.Sc. Agric (Hons) (Technical Manager)
W. Marais (Head of Laboratory)

Date: 2013/10/08

APPENDIX C

Lab Results - Water Samples

WATERLAB

WATERLAB (Pty) Ltd

Reg. No.: 1983/009165/07 V.A.T. No.: 4130107891

Building D
The Woods
41 De Havilland Cresent
Persequor Techno Park
Meiring Naudé Drive
Pretoria

P.O. Box 283
Persequor Park, 0020
Tel: +2712 – 349 – 1066
Fax: +2712 – 349 – 2064
e-mail: admin@waterlab.co.za

sanas Testing Laboratory
SANAS Accredited Testing Laboratory
No. T0391

CERTIFICATE OF ANALYSES
GENERAL WATER QUALITY PARAMETERS

Date received: 2013 - 09 - 20 **Date completed:** 2013 - 10 - 07

Project number: 1000 **Report number: 42074** **Order number: -**

Client name: Inkomati Catchment Management Agency

Contact person: Mr. F. Roux
Contact person: Mr. T. Rasiuba

Address: Private Bag X11214 Nelspruit 1200

e-mail: hydrocynus@mweb.co.za
e-mail: rasiubat@inkomaticma.co.za

Telephone: 013 753 9000 **Facsimile: 013 753 2786** **Mobile: 082 366 7708**

(Unless specified otherwise)	Method Identification	Date Analyzed	Sample Identification					
			USM1	USM2	USM3	USM4	USM5	USM6
Sample Number			18626	18627	18628	18629	18630	18631
pH – Value at 25°C LAB001	W	2013-09-23	8.0	7.9	7.9	7.6	7.5	7.9
Electrical Conductivity in mS/m at 25°C	WLAB002	2013-09-26	11.9	12.0	9.9	18.4	6.9	5.3
Chloride as Cl	WLAB046	2013-09-30	<5	<5	<5	17	6	<5
Sulphate as SO_4	WLAB046	2013-09-30	6	8	<5	5	<5	7
Nitrate as N	WLAB046	2013-09-30	0.4	0.4	0.2	0.3	<0.2	0.4
Nitrite as N	WLAB046	2013-09-30	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ortho Phosphate as P	WLAB046	2013-09-30	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Chemical Oxygen Demand as O_2 (Total)	WLAB018	2013-10-02	<10	<10	<10	<10	<10	<10
E. Coli / 100 m*l**	WLAB021	2013-09-19	59	78	10	10	48	200
Free & Saline Ammonia as N	WLAB046	2013-09-30	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Sodium as Na LAB015	W	2013-10-02	3	3	3	10	7	3
Copper as Cu (Dissolved)	WLAB015	2013-10-02	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Iron as Fe (Dissolved)	WLAB015	2013-10-02	0.186	0.044	0.033	0.082	1.35	0.044
Manganese as Mn (Dissolved)	WLAB015	2013-10-02	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025

E. Nkabinde

Technical Signatory

WATERLAB

WATERLAB (Pty) Ltd

Reg. No.: 1983/009165/07 V.A.T. No.: 4130107891

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e-mail: admin@waterlab.co.za

SANAS Accredited Testing Laboratory
No. T0391

CERTIFICATE OF ANALYSES
GENERAL WATER QUALITY PARAMETERS

Date received: 2013 - 09 - 20
Date completed: 2013 - 10 - 07
Project number: 1000 **Report number: 42074** **Order number: -**

Client name: Inkomati Catchment Management Agency
Contact person: Mr. F. Roux
Contact person: Mr. T. Rasiuba
Address: Private Bag X11214 Nelspruit 1200
e-mail: hydrocynus@mweb.co.za
e-mail: rasiubat@inkomaticma.co.za
Telephone: 013 753 9000 **Facsimile: 013 753 2786** **Mobile: 082 366 7708**

(Unless specified otherwise)	Method Identification	Date Analyzed	Sample Identification					
			USM7	USM8	USM9	USM10/1	USM10/2	USM12
Sample Number			18632	18633	18634	18635	18636	18637
pH – Value at 25°C LAB001	W	2013-09-23	7.6	7.8	7.7	7.5	8.0	7.6
Electrical Conductivity in mS/m at 25°C	LWB002	2013-09-26	12.4	6.4	3.9	12.1	4.3	3.6
Chloride as Cl	WLAB046	2013-09-30	<5	<5	7	<5	<5	<5
Sulphate as SO_4	WLAB046	2013-09-30	<5	7	<5	<5	7	<5
Nitrate as N	WLAB046	2013-09-30	<0.2	0.5	<0.2	0.2	0.5	<0.2
Nitrite as N	WLAB046	2013-09-30	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ortho Phosphate as P	WLAB046	2013-09-30	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Chemical Oxygen Demand as O_2 (Total)	WLAB018	2013-10-02	<10	<10	<10	<10	<10	<10
E. Coli / 100 m*	WLAB021	2013-09-19	50	1 200	180	8	1 600	36
Free & Saline Ammonia as N	WLAB046	2013-09-30	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Sodium as Na LAB015	W	2013-10-02	5	3	7	4	3	5
Copper as Cu (Dissolved)	WLAB015	2013-10-02	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Iron as Fe (Dissolved)	WLAB015	2013-10-02	0.187	<0.025	0.363	0.064	0.025	0.152
Manganese as Mn (Dissolved)	WLAB015	2013-10-02	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025

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SANAS Accredited Testing Laboratory
No. T0391

CERTIFICATE OF ANALYSES
GENERAL WATER QUALITY PARAMETERS

Date received: 2013 - 09 - 20 **Date completed:** 2013 - 10 - 07

Project number: 1000 **Report number: 42074** **Order number: -**

Client name: Inkomati Catchment Management Agency

Contact person: Mr. F. Roux
Contact person: Mr. T. Rasiuba

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(Unless specified otherwise)	Method Identification	Date Analyzed	Sample Identification				
			USM13	USM14	USM15	USM16	USM17
Sample Number			18638	18639	18640	18641	18642
pH – Value at 25°C LAB001	W	2013-09-23	7.4	8.0	7.8	7.7	8.1
Electrical Conductivity in mS/m at 25°C	W LAB002	2013-09-26	12.8	12.9	6.0	13.9	14.5
Chloride as Cl	WLAB046	2013-09-30	<5	<5	<5	<5	<5
Sulphate as SO_4	WLAB046	2013-09-30	<5	7	7	<5	7
Nitrate as N	WLAB046	2013-09-30	0.4	0.4	0.5	0.3	0.6
Nitrite as N	WLAB046	2013-09-30	<0.1	<0.1	<0.1	<0.1	0.2
Ortho Phosphate as P	WLAB046	2013-09-30	<0.05	<0.05	<0.05	<0.05	<0.05
Chemical Oxygen Demand as O_2 (Total) *	WLAB018	2013-10-02	<10	<10	<10	<10	<10
E. Coli / 100 mℓ*	WLAB021	2013-09-19	9	210	2 000	74	24
Free & Saline Ammonia as N	WLAB046	2013-09-30	<0.2	<0.2	<0.2	<0.2	<0.2
Sodium as Na LAB015	W	2013-10-02	2	2	2	2	2
Copper as Cu (Dissolved)	WLAB015	2013-10-02	<0.025	<0.025	<0.025	<0.025	<0.025
Iron as Fe (Dissolved)	WLAB015	2013-10-02	<0.025	0.048	0.033	0.060	0.047
Manganese as Mn (Dissolved)	WLAB015	2013-10-02	<0.025	<0.025	<0.025	<0.025	<0.025

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(Unless specified otherwise)	Method Identification	Date Analyzed	Sample Identification				
			USM18	USM19	USM20	USM21	USM22
Sample Number			18643	18644	18645	18646	18647
pH – Value at 25°C LAB001	W	2013-09-23	7.8	8.2	7.9	7.8	7.8
Electrical Conductivity in mS/m at 25°C LAB002	W	2013-09-26	14.5	21.2	7.5	8.0	7.4
Chloride as Cl	WLAB046	2013-09-30	<5	<5	<5	<5	<5
Sulphate as SO_4	WLAB046	2013-09-30	10	7	<5	<5	<5
Nitrate as N	WLAB046	2013-09-30	1.2	0.2	0.2	<0.2	0.2
Nitrite as N	WLAB046	2013-09-30	<0.1	<0.1	<0.1	<0.1	<0.1
Ortho Phosphate as P	WLAB046	2013-09-30	<0.05	<0.05	<0.05	<0.05	<0.05
Chemical Oxygen Demand as O_2 (Total) *	WLAB018	2013-10-02	<10	<10	<10	<10	<10
E. Coli / 100 m?*	WLAB021	2013-09-19	2 000	140	16	25	8
Free & Saline Ammonia as N	WLAB046	2013-09-30	<0.2	<0.2	<0.2	<0.2	<0.2
Sodium as Na LAB015	W	2013-10-02	3	2	2	<2	2
Copper as Cu (Dissolved)	WLAB015	2013-10-02	<0.025	<0.025	<0.025	<0.025	<0.025
Iron as Fe (Dissolved)	WLAB015	2013-10-02	0.053	<0.025	0.050	0.085	0.031
Manganese as Mn (Dissolved)	WLAB015	2013-10-02	<0.025	<0.025	<0.025	<0.025	<0.025

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roundworms (Nematoda). None of these seemed to have a negative effect on the crabs and no lesions were observed.

MATERIAL & METHODS

Crabs were collected in the Sabie River during March and September 2013 and couriered live to Bloemfontein in moist Styrofoam crates. On arrival the crabs were kept alive until each one was dissected. The crabs were mechanically killed as no chemical could be used to anesthetise them as this might have a negative effect on the symbionts that occur on the gills. All the crabs were also externally examined for any symbionts, as well as closer examination of the mouthparts. The dorsal carapace was removed to reveal the gill filaments, which were removed using fine tweezers and scissors. The loose gill filaments were placed in a little bit of water in a petri dish and examined using a dissecting microscope. Sections of the gill lamellae were also placed on microscope slides and examined using a compound microscope. This was the only way to detect the presence of any ciliates. Digital images were taken of live observations of both the rotifers and ciliates found.

Rotifers found were fixed in 70% etOH, and 4% or 10% buffered neutral formalin (BNF). The few ciliates colonies that were found were fixed 10% BNF and/or Bouins and then transferred to 70% etOH. Sections of the gills were prepared for Scanning electron microscopy, using standard methods. Some of the ciliates were stained using Mayer's Haematoxyil in order to observe internal structures.

In order to determine the infestation levels, a scale was used quantify the number of symbionts found. A 1x represents less than 20 individual rotifers per gill filament, 2x represents a higher infestation and 3X was when the entire gill arch was covered by rotifers. The rotifer symbionts were not found on the gill lamellae, but were concentrated on the anterior and posterior margin of the gill arch. Notes were also made if all of the 12 gill filaments per crab were infested or not. The percentage of cover per gill arch was determined by counting the individual specimens per arch (after fixation). In the case of the ciliates, the colonies we encountered were counted.

RESULTS AND DISCUSSION

found on the gill lamellae, but were concentrated on the anterior and posterior margin of the gill arch (see Figs 2A, B & E). In some case some of these filaments did not harbour any symbionts. In some cases where a higher infestation per crab was observed, six or more of the gills were infested and in two cases all 12 gill arches were infested.

In the majority of the cases a low infestation, with only up to 20 rotifers were found attached to the anter ior margin of the arch, representing a surface area of 5% of the gill arch margin. A total of 54 crabs from all the 11 localities had infestations falling in this category. Of the total of 65 crabs, six had a slightly higher infestation (up to 80 rotifers on the anterior side if the arch, Fig. 2A) that presents a surface area of 70% of the anterior gill arch margin. Five of the crabs had more than 100 rotifers on the anterior as well as posterior side of the gill arch covering more than 90% of the gill ach margin. In the majority of the cases the rotifers were attached to the gill arch anterior margin (Figs. 2E & F) and only in a few cases were small colonies found at the tips of the filaments (Fig. 2C). Some individuals also detached from the gills and swam actively in the petri dish (Fig. 2D), suggesting that these rotifers are not true parasites, but probably only attach to the gill arch for transport and food.

SESSILE CILIATES

Many ciliate species (apostomatids, peritrichs, suctorians, heterotrichs and chonotrichs) have been reported from a variety of crustacean host (Fernandez-Leborans 1997). The majority of former studies focused on species descriptions, and only a few papers deals with the ecology or relationship with the host. In the study conducted by Fernandez-Leborans (1997) on the blue crab, he found that *Zoothamnium* and *Cothurnia* specimens were found randomly on the crab body. In the case of *Chilodochona* they mostly occurred on the buccal appendages. This was unexpected, as in most cases the gill surfaces is the most common place for epibiotic ciliates and the absence of ciliates from the gills on the crabs in the study done by Fernandez-Leborans (1997) was unexplained. This is in contrast to what we observed for the South African crabs, were the bodies and appendages of the crabs hosted no symbionts and sessile ciliates were found only the gill lamellae.

Peritrichous ciliates of the genera *Lagenophrys, Epistylis* (Epistylididae) and *Zoothamnium* (Vorticellidae) have been recorded from the gill lamellae of marine and freshwater crabs.

Lagenophryidae: Loricate, solitary, stalkless, lorica in shape of flattened hemisphere, with surface glued to host's integument.

Epistylididae: Generally stalked, with stalk often non-contractile (but with highly contractile body), solitary or colonial, zooids can be up to 600 µm in size, abundant in freshwater habitats, free-living or symphorionts on diverse host range.

Vorticellidae: With contractile stalk, all species colonial except for 2 genera. Zooids not independently contractile among colonial forms, species attach to inanimate objects as well as plants and aquatic animals.

More than 51 *Lagenophrys* species have been described from a variety of crustacean hosts, demonstrating a high degree of host-specificity (Crouch 1966). This is even justifiably used as taxonomic criterion in species descriptions of *Lagenophrys* species, well before molecular studies were developed (Corliss & Brough 1965). In the case of *Epistylis* they are found as epibionts of molluscs, fish, amphibians and crustaceans, thus they are less host-specific. Crouch (1966) found that an increase in the numbers of epibionts, combined with additional infections of endoparasites, low oxygen tension in warmer water, over crowding of the crabs and injuries can all contribute to general anoxia in crabs.

Thirteen of the 65 crabs from the Sabie River had a very low infestation of sessi le ciliates; we found only one colony of ciliates per gill lamellae on one of the gills. The ciliates were identified as belonging to the genus *Epistylis* (Peritrichia: Epistylididae), due to the non-contractile stalk, shape of the body and nuclear apparatus. Two forms were observed, one with a more slender stalk with two zooids (Fig. 1A), and a second representative which had a shorter, more stubby stalk, branching into more zooids (Figs. 1B-D).

NEMATODA

In three of the samples dissected (see Tabl e 1 at US MO6 and Table 2 at USM 6 headwaters) we found a few nematodes. Holovachov *et al.* (2010) found an epibiotic nematode associated with a gastropod, but did refer to other epibiotic nematodes known from crabs. It seems that representatives of the Order Monhysterida do occur on the gills of land crabs (although these were recorded from the Caribbean). It was rst found in the early 1920's, but has since been recorded more in the literature. The only other reference to epibiotic Nematode on crabs was by Chesunoc (1987), but also from land crabs.

Holovachov *et al*. (2010) came to the conclusion that the exact mechanism of symbiotic associations of nematodes with aquatic invertebrates (snails in their case) are unknown. It seems possible that the nematodes find food and shelter on the hosts, and that could be the same for the few nematodes that were found crawling over the gills from the Sabie River crabs.

CONCLUDING REMARKS

The rotifers and peritrichs found on the gills of *P. sidneyi* are probably more symbiotic than parasitic. In our opinion the respiratory area of the crabs are not damaged, thus these symbionts should not have any adverse effect on the crabs. As a matter of fact, they are very probably to the advantage of the crab, as the filtering movement of the corona of the rotifers as well as the filter feeding action of the ciliates probably assist in ventilation of the gills when the crabs are out of the water or in water with low oxygen concentrations.

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Table 1. Data sheet of symbionts found on *Potamonauteus sidneyi* from Sabie River South Africa, during the March dissection. 1x = low infestation, up to 20 individuals, 2x slightly higher infestation and 3x represents where the entire gill arch were covered by rotifers.

USM31	**USM06**	**USM17**
1) DEAD ON ARRIVAL, 1x rotifers	1) 1x rotifers	1) 2x of rotifers
2) 1x rotifers	2) Nematode, small	2) 2x rotifers
3) 1x rotifers	3) 1x rotifers	3) 1x rotifers
4) 1x rotifers	4) 1x rotifers	4) 2-3x rotifers
5) 1x rotifers	5) 1x rotifers, few Nematode worms	5) 1x rotifers
6) 1x rotifers	6) DEAD ON ARRIVAL, not intact anymore, not possible to dissect	6) 1x rotifers
USM25	**USM14**	**USM01**
1) Crab almost dead 1x rotifers	1) no symbionts	1) 2x rotifers Ciliates (1 colony)
2) 1x rotifers	2) 1x rotifers	2) 2x rotifers
3) 1x rotifers	3) no symbionts	3) 3x rotifers ciliates (1 colony)
4) 1x rotifers	4) 1x rotifers	4) 1x rotifers ciliates (1 colony)
5) 1x rotifers	5) 1x rotifers 1x Ciliates	5) 1x rotifers ciliates (1 colony)
6) 1x rotifers	6) 1x rotifers Few ciliates zooids	6) 2x rotifers Ciliates (1 colony)

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Table 1. Data sheet of symbionts found on *Potamonauteus sidneyi* from Sabie River South Africa, during the March dissection. 1x = low infestation, up to 20 individuals, 2x slightly higher infestation and 3x represents where the entire gill arch were covered by rotifers.

USM31	**USM06**	**USM17**
1) DEAD ON ARRIVAL, 1x rotifers	1) 1x rotifers	1) 2x of rotifers
2) 1x rotifers	2) Nematode, small	2) 2x rotifers
3) 1x rotifers	3) 1x rotifers	3) 1x rotifers
4) 1x rotifers	4) 1x rotifers	4) 2-3x rotifers
5) 1x rotifers	5) 1x rotifers, few Nematode worms	5) 1x rotifers
6) 1x rotifers	6) DEAD ON ARRIVAL, not intact anymore, not possible to dissect	6) 1x rotifers
USM25	**USM14**	**USM01**
1) Crab almost dead 1x rotifers	1) no symbionts	1) 2x rotifers Ciliates (1 colony)
2) 1x rotifers	2) 1x rotifers	2) 2x rotifers
3) 1x rotifers	3) no symbionts	3) 3x rotifers ciliates (1 colony)
4) 1x rotifers	4) 1x rotifers	4) 1x rotifers ciliates (1 colony)
5) 1x rotifers	5) 1x rotifers 1x Ciliates	5) 1x rotifers ciliates (1 colony)
6) 1x rotifers	6) 1x rotifers Few ciliates zooids	6) 2x rotifers Ciliates (1 colony)

Table 2. Data sheet of symbionts found on *Potamonauteus sidneyi* from Sabie River South Africa, during the September dissection. 1x = low infestation, up to 20 individuals, 2x slightly higher infestation and 3x represents where the entire gill arch were covered by rotifers.

USM3	**USM6 Headwaters**	**USM 2**
1) Male 25.9 gr 1x rotifers	1) Male 18,6 gr no symbionts	1) Male 17.9 gr 1x rotifers
2) Female 23.8 gr 1x rotifers few loose ciliate zooids	2) Female 41.9 gr gravid 2 worms, Nematodes	2) Male 17.2 gr 1x rotifers
3) Female 20,9 gr 1x Ciliates	3) male 36.4 gr 1x rotifers	3) Female 16. 9 gr 1x rotifers
4) Female 24.9 gr 1x rotifers	4) Male 21.6 gr 1x rotifers	4) Male 30.4 gr, gills dirty 1x rotifers
5) Female 23.9 gr 1x rotifers	5) Female 61 gr 1x rotifers	5) Male 32gr 1x rotifers
6) Female, 33.7 gr 3x rotifers	6) Male mature 53.9 gr 2x rotifers	6) Male 31.6 gr gills dirty (algae on ridge) 1x rotifers

USM 5 Sabieshoek	**USM4 Sewage**
1) Male 30.3 gr 1x rotifers	1) Male 22.9 gr 1x rotifers
2) Male 18.1 gr 3x rotifers	2) Female 34,2 gr leech on leg of crab 1x rotifers Ciliates (1 colony)
3) Female 22 gr (all of the gills, cover groove) 3x rotifers	3) Male 30.4 gr 3x rotifers (all the gills, cover groove)
4) Female 25.9 gr 1x rotifers	4) Male 22.6 gr 1x rotifers ciliates (1 colony)
5) Male 21.5 gr 1x rotifesa ciliates (1 colony)	5) Female gravid 28 gr 1x rotifers ciliates (1 colony)
6) female gravid 27.8 gr 2x rotifers ciliates (1 colony)	6) Female 34.2 gr gravid 2x rotifers ciliates (1 colony)

APPENDIX E

Specialist Report - Fish

Fish assemblage of the Upper Sabie River.

Prepared by:

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Date:

December 2013

Mpumalanga
TOURISM AND PARKS AGENCY

3. METHODS

The general approach used for this study was based on the rapid appraisal methods recommended by the Department of Water Affairs and Forestry in their guidelines for Resource Directed Measures for the Protection of Water Resources. Aquatic bio-assessment is an essential component of ecological risk assessment. It aims to measure present biological conditions and trends in an aquatic ecosystem and relate the observed v ariation to changes in available habitat. The availability of suitable habitat for aquatic biota is dictated by the physical drivers of the aquatic ecosystem such as water quality, geomorphology and hydrology

Aquatic biodiversity provide an integrative perspective of rivers as ecosystems by integrating pattern (structure) with process (function). Biodiversity can also serve as a link between spatial and temporal phenomena and can explain the roles of functional processes in ecosystems. The purpose of this study was to use aspects of selected resident aquatic biodiversity to characterize the existence and severity of impairments in the Sabie River and to try and identify any sources and causes of impairment relating to catchment modifications. Aquatic bio-monitoring is an essential component of ecological risk assessment and aims to measure pr esent biological conditions and trends in the aquatic ecosystem. It attempts to relate the observed variation to changes in available habitat, as dictated by physical system drivers of the system such as water quality, geomorphology, and hydrology (Figure 2 & 3) (Kleynhans & Louw, 2008). Several of the aquatic species and taxa that have been recorded in the Sabie River are considered highly sensitive to changes in the above-mentioned physical drivers and are expected to respond rapidly to any changes.

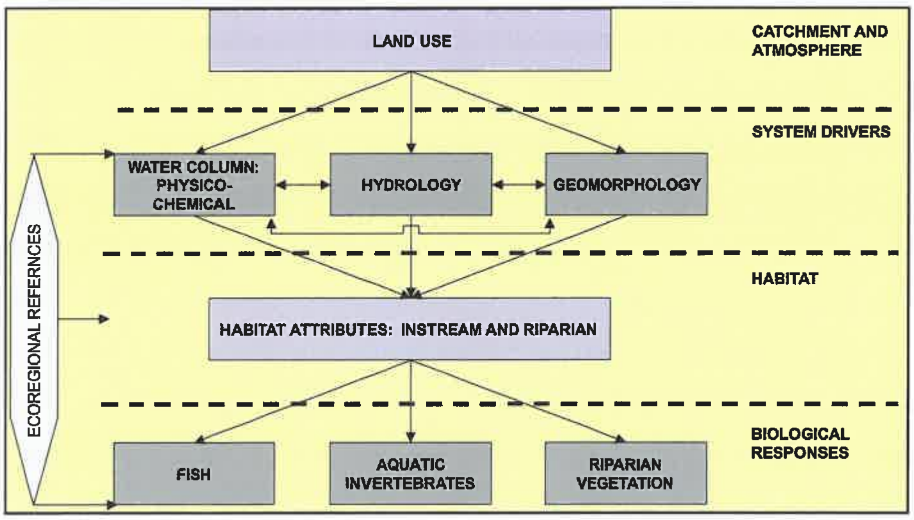


Figure 2: A simplified integration of influence of land use on physical driver determinants, habitats and the associated biological responses.

natalensis, Amphilius uranoscopus and *Tilapia sparrmanii*. During the **low flow** survey all the above species excluding *Amphilius natalensis* were recorded. Both the highly sensitive *Amphilius* species are rheophylic, flow dependant species with a high (4.6 to 5) flow-depth preference for fast deep and fast shallow fish velocity depth classes. Both these species are totally intolerant (4.8 to 4.9) to reduced flow conditions, have a very high (5) preference to substrate and is highly intolerant to water quality changes (4.8 to 4.9). Their absence and relative low abundance as recorded at this monitoring site can be explained based on these intolerant ratings. Excessive siltation and sedimentation in the upper catchment results in filling of interstitial spaces modifying the substratum (boulders, cobbles, stones and gravel) causing reduced available fi sh habitat. This modified in-stream fish habitat impacts negatively on these sensitive species. The age classes for both the *Amphilius* species reflect sub-adults and adults without any juveniles recorded following the breeding season. This age class structure therefore indicates disrupted breeding functions of both species.

Barbus anoplus and *Tilapia sparrmanii* were recorded in moderate abundance. These limnophylic species favours s low flowing water with sufficient plant and root cover. Based on the intolerance rating both species are moderately tolerant to no flow conditions and modified water quality (physico-chemical). Barbus anoplus were collected in relative abundance and the age classes reflect juveniles, sub-adults and adults indicating that the breeding functions is not yet disrupted. Not all the expected fish species are present within th is resource unit and the Frequency of Occurrence (FROC) of some species has been reduced from the reference conditions. The Frequency of Occurrence (FROC) of the recorded species has furthermore been altered as a result of habitat deterioration due to excessive siltation and sedimentation, as well as the impact of the predatory alien and invasive species *Oncorhynchus mykiss*.

No longfin eels (*Anguilla mossambica*) were co llected in the upper reaches during this survey. This species is catadromous meaning that they live for many years in freshwater before they migrate down to the marine environment to breed in the ocean near Madagascar. Eel larvae metamorphose into glass eels and then become elvers before they may migrate upstream into freshwater to colonise the rivers until maturity, before they migrate back to the sea to breed again. The presence of large dams, downstream creates largely unsurpassable barriers to the migrations of this species. Although infrequent records are still recorded in the Sabie River, it is doubtful that this species will be able to maintain population in this river in future and still occur in any significant numbers.

The CPUE (catch per unit effort) for the **high flow** is 1.4 (26 minute) and for the **low flow** 0.93 (30 minutes) which indicate a reduced CPU at this site during the low flow period. The reason for this can be ascribed to the loss of one species as well as the reduced abundance of rheophylic fish species.

A Fish Response Assessment Index (FRAI) score of 70.3% was calculated for the **high flow** for this reach based on all ava ilable information, placing this reach in an Ecological Class C (Moderately impaired with a moderate diversity and low abundance of species). The Ecological class for the **low flow** based on FRAI is calculated at 62.6% and a C/D class (moderately to considerably impaired with a moderate diversity of taxa consisting mainly of tolerant species).

The relatively low ecological class (CD) can be related to excessive sedimentati on and the presence of predatory introduced alien fish species rainbow trout (*Oncorhynchus mykiss*).

Impacts and mitigation

The fish assemblage present in this reach is impacted by rainbow trout (*Oncorhynchus mykiss*), an introduced alien species, which are primarily stocked for recreational fishing. This reach is within the proclaimed fly fishing zone and stocking is regulated by provincial legislation. The low FRAI value was influenced by the impact of the predatory alien and invasive fish species rainbow trout (*Oncorhynchus mykiss*), as well as from excessive sedimentation from a degraded catchment resulting in reduced available fish habitat.

Table 2: Site 1 : USM 25 – Sabieshoek : Species collected in different fish velocity-depth classes

USM 25 : Sabieshoek : X31A-00799														
Expected fish species Sabie Mainstem	Fish species collected		Total individuals		Juveniles		Sub adults		Adults		Slow deep	Slow shallow	Fast deep	Fast shallow
	High flow	Low flow	High flow	Low flow	High flow	Low flow	High flow	Low flow	High flow	Low flow				
Anguillidae														
Anguilla mossambica														
Cyprinidae														
Barbus anoplus	X	X	18	23	X		X		X	X	0	4	0	2
Amphiliidae														
Amphilius natalensis	X		3				X		X		0	0	0	5
Amphilius uranoscopus	X	X	8	2			X	X	X	X	0	0	0	5
Cichlidae														
Tilapia sparrmanii	X	X	7	3			X	X	X	X	3	4	0	2
Number of species	4	3												
Number of individuals			36	28										
CPUE for electric shocking	High flow: 1.4 (26 minute)				Low flow: 0.93 (30 minute)									
Ecological class based on FRAI	High flow: C class (70.3%)				Low flow: C/D class (62.6%)									

0 = absent 1=rare 2=sparse 3=moderate 4=abundant 5=very abundant

4.2. SQ Reach X31B-00757

Three monitoring sites USM 17 Sabie sewerage, USM 14 Below Rietfontein Mine and USM 8 Frankfort, X31B-00757 were selected to represent this relative long reach with a total length of 16.32km. The reason for the selection of three biomonitoring sites for this reach is to ensure that all impacts from Sabie town as well as tributaries are recorded

Site 2: USM 17 – Sabie Sewerage

General description

This biomonitoring site is representative of an upper foothill stream, below 1000 m.a.s.l. This stream is characterised as a moderately inclined mountain stream, dominated by in-stream boulders with increased flow velocities, and a high diversity of habitat types, which includes riffles and runs, cascades and pools. The catchment has largely been transformed to monoculture forestry (mainly eucalyptus) with a well-developed riparian zone which provide additional habitat such as overhanging vegetation with undercut banks with dense stands of alien invasive species. Of concern at this site is the malfunctioning of the Sabie sewerage works as well as urbanisation impacts of the upstream Sabie town. Also impacting this site is the tributary, the Klein Sabie, flowing from the industrial zone and residential zone with reduced water quality conditions, that confluence just upstream from this monitoring site.

This site is in the Sabie mainstem downstream of Sabie town and situated close to the Sabie sewerage works. Unfortunately this site is largely impacted by the forestry industry within this upper catchment, as well as by urbanisation impacts of Sabie town. The fish velocity depth classes recorded were **slow deep** (moderate), **fast shallow** (abundant) and **slow shallow** (sparse to abundant) with **fast deep** (sparse to moderate). The fish cover present identified was moderate with moderate overhanging vegetation and moderate undercut banks and root wads. The substrate rated moderate in both the fast and slow fish velocity depth classes. Sediment and siltation deposits were recorded in the pools where stream velocity is reduced encouraging deposition.

Fish assemblage

During the **high flow** survey at this biomonitoring site four of the eight expected fish species were recorded, whilst three of the eight expected species were recorded during the **low flow** surveys. Species collected during the **high flow** surveys were *Varicorhinus nelspruitensis, Amphilius uranoscopus, Chiloglanis anoterus* and *Tilapia sparrmanii.* During the **low flow** survey all the above species excluding *Amphilius uranoscopus* we re recorded. During both surveys species were collected at a low abundance with skewed age class distributions. The fish assemblage was dominated by rheophylic flow dependant fish species.

The highly sensitive *Amphilius uranoscopus, Varicorhinus nelspruitensis and Chiloglanis anoterus* species are rheophylic, flow dependant species with a high (4.3 to 5) flow-depth preference for fast deep and fast shallow fish velocity depth classes. *Amphilius uranoscopus and Chiloglanis anoter us* are totally intolerant (4.8 to 4.9) to reduced flow conditions, while *Varicorhinus nelspruitensis* is moderately intolerant (3.6) to reduced flow conditions. All three species have a very high (5) preference to substrate and *Amphilius uranoscopus and Chiloglanis anoterus* is highly intolerant to water quality changes (4.7 to 4.9) whereas *Varicorhinus nelspruitensis* is moderately tolerant to reduced water quality . Thei r relative low abundance as recorded at this monitoring site can be explained based on these intolerant ratings. *Tilapia sparrmanii* is a limnophylic species that favours slow flowing water with sufficient plant and root cover. Based on the intolerance rating this species is moderately tolerant to no flow conditions and modified water quality (physico-chemical).

Not all the expected fish species are present within this re source unit and the Frequency of Occurrence (FROC) of some species has been reduced from the reference conditions. The Frequency of Occurrence (FROC) of the recorded species has furthermore been altered as a result of reduced water quality due to urbanisation and sewerage impacts, as well as by habitat deterioration due to siltation and sedimentation.

The age classes for all the rheophylic species collected were skewed indicat ing disrupted breeding functions. The age classes for the tolerant *Tilapia sparrmanii* reflected juveniles, sub-adults and adults, indicating that the breeding function for this species is not disrupted at present and a viable population exist.

The CPUE (catch per unit effort) for the **high flow** is 0.60 (30 minute) and for the low flow 0.60 (28 minutes). Both these CPUE values are extremely low for this reach indicating reduced con ditions. A Fish Response Assessment Index (FRAI) score of 73.8% was calculated for the **high flow** for this reach based on all available information, placing this reach in an Ecological Class C (Moderately impaired with a moderate diversity and low abundance of species). The Ecological class for the **low flow** based on FRAI is calculated at 61.1% and a C/D class (moderately to considerably impaired with a moderate diversity of taxa consisting mainly of tolerant species). The relative low ecological class (CD) can be related to reduced water quality and sediment deposition reducing available fish habitat.

Impacts and mitigation

This site is in the Sabie mainstem downstream of Sabie town and situated close to the Sabie sewerage works and is largely impacted by the forestry industry within this upper catchment, as well as by urbanisation impacts of Sabie town.

Table 3: Site 2: USM 17 – Sabie Sewerage: Species collected in different fish velocity-depth classes

USM 17 : Sabie Sewerage: X31B-00757														
Expected fish species Sabie Mainstem	Fish species collected		Total individuals		Juveniles		Sub adults		Adults		Slow deep	Slow shallow	Fast deep	Fast shallow
	High flow	Low flow	High flow	Low flow	High flow	Low flow	High flow	Low flow	High flow	Low flow				
Anguillidae														
Anguilla mossambica														
Cyprinidae														
Barbus anoplus														
Varicorhinus nelspruitensis	X	X	6	3			X	X	X		0	2	3	4
Amphiliidae														
Amphilius natalensis														
Amphilius uranoscopus	X		1						X		0	0	0	5
Mochokidae														
Chiloglanus anoterus	X	X	8	2			X		X	X	0	0	2	5
Cichlidae														
Pseudocrenilabrus philander														
Tilapia sparrmanii	X	X	3	12		X		X	X	X	3	4	0	2
Number of species	4	3												
Number of individuals			18	17										
CPUE for electric shocking	High flow: 0.60 (30 minute)				Low flow: 0.60 (28 minute)									
Ecological class based on FRAI	High flow: C class (73.8%)				Low flow: C/D class (61.1%)									

0 = absent 1=rare 2=sparse 3=moderate 4=abundant 5=very abundant

Site 3: USM14 – Below Rietfontein Mine

General description

This aquatic habitat surveyed is downstream of the sewerage biomonitoring site, although still representative of an upper foothill stream below 1000 m.a.s.l. This stream can be characterised as a moderately inclined mountain stream, dominated by in-stream boulders with increased flow velocities, and a high diversity of habitat types, which includes riffles and runs, cascades and pools. The catchment has largely been transformed to monoculture forestry (mainly eucalyptus) with a well-developed riparian zone which provide additional habitat such as overhanging vegetation with undercut banks with dense stands of alien invasive species. This site is still impacted by the malfunctioning Sabie sewerage works as well as urbanisation impacts of the upstream Sabie town. Close to this biomonitoring site is a decommissi oned old gold mine on the banks of the Sabie River. Acid mine drainage still occur from this site reducing the water quality conditions. Furthermore impacting on this site through an unnamed tributary is an existing gold mine (TGME) which is being re-worked. This activity leads to excessive sedimentation and siltation and furthermore reduces the water quality.

The fish velocity depth classes recorded were **slow deep** (moderate), **fast shallow** (very abundant) and **slow shallow** (sparse to abundant) with **fast deep** (moderate). The fish cover present identified was moderate with moderate overhangin g vegetation and moderate undercut banks and root wads. The substrate rated moderate in both the fast and slow fish velocity depth classes. This is due to observed sedimentation and siltation, resulting from the impacts of the mining and forestry related activities upstream of this site.

Fish assemblage

The fish assemblage recorded at this site is fairly similar to that described for the Sabie sewerage biomonitoring site. The same fish species were recorded during both **high** and **low flow** surveys with relatively low abundance. The species collected during both the **high** and **low flow** surveys were *Varicorhinus nelspruitensis, Amphilius uranoscopus, Chiloglanis anoterus* and *Tilapia sparrmanii*. Once again the fish assemblage was dominated by rheophylic flow dependant fish species.

The relative low abundance of recorded species at this monitoring sit e can be explained based on the intolerant ratings (see full description at Sabie sewerage site). Not all the expected fish species are present within this resource unit and the Frequency of Occurrence (FROC) of some species has been reduced from the reference conditions. The Frequency of Occurrence (FROC) of the recorded species has furthermore been altered as a result of reduced water quality due to urbanisation and sewerage impacts upstream at Sabie town. The low frequency of occurrence within the rheophylic species can also be related to reduced habitat conditions and available habitat due to siltation and sedimentation as a result of bank instability and erosion caused by the forestry and mining activities associated with this river reach.

The age classes for all the collected species were skewed reflecting sub-adults and adults. The absence of juveniles following the breeding season indicates that breeding function is disrupted.

The CPUE (catch per unit effort) for the **high flow** is 1.70 (27 minute) and for the **low flow** 0.75 (28 minutes). The extreme low value obtained during the **low flow** would be an indication that as a result of reduced flow velocity the water quality further deteriorates impacting on the intolerance (physico-chemical) rating of sensitive rheophylic fish species. A Fish Response Assessment Index (FRAI) score of 76.6% was calculated for the **high flow** for this reach based on all available information, placing this reach in an Ecological Class C (moderately impaired with a moderate diversity and low abundance of species). The Ecological class for the **low flow** based on FRAI is calculated at 71.0% and is also a C class (moderately impaired with a moderate diversity and low abundance of species). The relative low ecological class (C) can be related to reduced water quality and sediment deposition reducing available instream fish habitat.

Impacts and mitigation

This site is still impacted by the urbanisation related effects on water quality as well as by dissolved salts EC) from decommissioned gold mines in the area and the re-working of an old existing mine. Siltation and sedimentation due to bank instability and erosion caused by forestry related act ivities further decrease habitat conditions.

Table 4: Site 3 USM14 – Below Rietfontein Mine: Species collected in different fish velocity-depth classes

USM 14 : Below Rietfontein Mine : X31B-00757														
Expected fish species Sabie Mainstem	Fish species collected		Total individuals		Juveniles		Sub adults		Adults		Slow deep	Slow shallow	Fast deep	Fast shallow
	High flow	Low flow	High flow	Low flow	High flow	Low flow	High flow	Low flow	High flow	Low flow				
Anguillidae														
Anguilla mossambica														
Cyprinidae														
Barbus anoplus														
Varicorhinus nelspruitensis	X	X	28	9			X	X	X	X	0	2	3	4
Amphiliidae														
Amphilius natalensis														
Amphilius uranoscopus	X	X	2	1				X	X		0	0	0	5
Mochokidae														
Chiloglanus anoterus	X	X	11	3			X	X	X		0	0	2	5
Cichlidae														
Pseudocrenilabrus philander														
Tilapia sparrmanii	X	X	6	8			X	X		X	3	4	0	2
Number of species	**4**	**4**												
Number of individuals			**47**	**21**										
CPUE for electric shocking	**High flow: 1.70 (27 minute)**				**Low flow: 0.75 (28minute)**									
Ecological class based on FRAI	**High flow: C class (76.6 %)**				**Low flow: C class (71.0 %)**									

0 = absent 1=rare 2=sparse 3=moderate 4=abundant 5=very abundant

Site 4 USM 8 – Frankfort

General description

This aquatic habitat is at the lower end of reach X31B-00757 but is still representative of an upper foothill stream below 1000 m.a.s.l. This monitoring site is downstream of the USM14 – Below Rietfontein mine site at a low water bridge and can be characterised as a moderately inclined mountain stream, dominated by in-stream boulders with increased flow velocities, and a high diversity of habitat types. Surveys were conducted upstream and downstream of the low water bridge. The upstream site consists of a large longitudinal pool. The downstream site includes a plunge pool with successive riffles and runs. The catchment has largely been transformed to monoculture forestry (mainly eucalyptus) with a well-developed riparian zone which provide additional habitat such as overhanging vegetation with undercut banks with dense stands of alien invasive species. Although reduced, this site is still impacted by the malfunctioning Sabie sewerage works and urbanisation impacts of the upstream Sabie town, during low flow conditions. Close to this biomonitoring site is a tributary, the Goudstroom, where due to forestry related activities high levels of sedimentation and siltation occurs.

The fish velocity depth classes recorded were **slow deep** (moder ate), **fast shallow** (abundant) and **slow shallow** (abundant) with **fast deep** (sparse). The fish cover present identified was moderate with moderate overhanging vegetation and moderate undercut banks and root wads. The substrate rated moderate in the fast and sparse in the slow fish velocity depth classes. This is due to observed sedimentation and siltation, resulting from the impacts of forestry related activities upstream of this site.

Fish assemblage

Eight of the nine expected indigenous fish species were collected during the **high flow** survey. During the **low flow** survey only six of the expected nine species were recorded. Species recorded during **high flow** includes *Anguilla mossambica, Barbus anoplus, Barbus unitaeniatus, Varicorhinus nelspruitensis, Amphilius uranoscopus, Chiloglanis anoterus, Pseudocrenilabrus philander* and *Tilapia sparrmanii*. The **low flow** surveys indicated the absence of *Barbus unitaeniatus* and *Anguilla mossambica*.

The flow sensitive rheophylic species included *Varicorhinus nelspruitensis, Amphilius uranoscopus* and *Chiloglanis anoterus* with a high (4.3 to 5) flow-depth preference for fast deep and fast shallow fish velocity depth classes. *Amphilius uranoscopus and Chiloglanis anoterus* are totally intolerant (4.8 to 4.9) to reduced flow conditi ons, while *Varicorhinus nelspruitensis* is moderately intolerant (3.6) to reduced flow conditions. All three species have a very high (5) preference to substrate and *Amphilius uranoscopus and Chiloglanis anoterus* is highly intolerant to water quality changes (4.7 to 4.9) whereas

Varicorhinus nelspruitensis is moderately tolerant to reduced water quality. *Barbus anoplus, Barbus unitaeniatus, Pseudocrenilabrus philander and Tilapia sparrmanii are* limnophylic species that favours slow flowing water with sufficient plant and root cover. Based on the intolerance rating these species are moderately tolerant to no flow conditions and modified water quality (physico-chemical).

One adult longfin eels (*Anguilla mossambica*) were collected in the upper reaches during this survey. This species is catadromous meaning that they live for many years in freshwater before they migrate down to the marine environment to breed in the ocean near Madagascar. Eel larvae metamorphose into glass eels and then become elvers before they may migrate upstream into freshwater to colonise the rivers until maturity, before they migrate back to the sea to br eed again. The presence of large dams, downstream creates largely unsurpassable barriers to the migrations of this species. Although infrequent records are still recorded in the Sabie River, it is doubtful that this species will be able to maintain population in this river in future and still occur in any significant numbers.

The relative low abundance of sensitive species and increase in abundance of more tolerant species during the **low flow** survey can be explained based on the intolerant ratings. Not all the expected fish species are present within this resource unit and the Frequency of Occurrence (FROC) of some species has been reduced from the reference conditions. The Frequency of Occurrence (FROC) of the recorded species has furthermore been altered as a result of reduced water quality due to urbanisation and sewerage impacts upstream at Sab ie town, as well as reduced habitat conditions due to siltation and sedimentation.

The age classes for all the collected species were skewed reflecting sub-adults and adults for most of the species collected, except for *Barbus anoplus* where juveniles were recorded in the **high flow** season. The absence of juveniles following the breeding season indicates that breeding function is disrupted at present.

The CPUE (catch per unit effort) for the **high flow** is 1.9 (36 minute) and for the **low flow** 2.67 (28 minutes). Although an increase is noted for the CPUE value for the **low flow** surveys, it can be explained that abundance of the non-sensitive species increased for this survey period. A Fish Response Assessment Index (FRAI) score of 76.4% was calculated for the **high flow** for this reach based on all available information, placing this reach in an Ecological Class C (moderately impaired with a moderate diversity and low abundance of species). The Ecological class for the **low flow** based on FRAI is calculated at 70.1% and is also a C class (moderately impaired with a moderate diversity and low abundance of species). The relative low ecological class (C) can be related to reduced water quality and sediment deposition reducing available instream fish habitat.

Impacts and mitigation

This site is still impacted by the urbanisation related effects on water quality. Siltation and sedimentation due to bank instability and erosion caused by forestry related activities further decrease habitat conditions.

Table 5: Site 4 USM 8 – Frankfort: Species collected in different fish velocity-depth classes

USM 8 : Frankfort: X31B-00757														
Expected fish species Sabie Mainstem	Fish species collected		Total individuals		Juveniles		Sub adults		Adults		Slow deep	Slow shallow	Fast deep	Fast shallow
	High flow	Low flow	High flow	Low flow	High flow	Low flow	High flow	Low flow	High flow	Low flow				
Anguillidae														
Anguilla mossambica	X		1				X				0	0	0	4
Cyprinidae														
Barbus anoplus	X	X	7	14	X		X	X	X	X	0	4	0	2
Barbus unitaeniatus	X		4						X		0	2	2	4
Varicorhinus nelspruitensis	X	X	8	17				X	X	X	0	2	3	4
Amphiliidae														
Amphilius natalensis														
Amphilius uranoscopus	X	X	17	7			X	X	X	X	0	0	0	5
Mochokidae														
Chiloglanus anoterus	X	X	17	9			X	X	X	X	0	0	2	5
Cichlidae														
Pseudocrenilabrus philander	X	X	5	18				X	X	X	3	4	0	2
Tilapia sparrmanii	X	X	11	10			X	X	X	X	3	4	0	2
Number of species	8	6												
Number of individuals			69	75										
CPUE for electric shocking	High flow: 1.9 (36minute)				Low flow: 2.67 (28minute)									
Ecological class based on FRAI	High flow: C class (76.4%)				Low flow: C class (70.1%)									

0 = absent 1=rare 2=sparse 3=moderate 4=abundant 5=very abundant

4.3. SQ Reach X31D-00772

Site 5 USM 2 – Brandwag

General description

This reach is representative of lower foothill stream, above 517 m.a.s.l. It is characterised by a low gradient, moderate sized stream with mainly riffles, runs and pools. This biomonitoring site is situated just downstream of the confluence with the Mac-Mac and Sabaan rivers. The Mac-Mac catchment has largely been transformed to monoculture forestry with high water quality conditions, whereas the Sabaan catchment has been largely modified to irrigational sub-tropical farming with increased organic enrichment (nitrates) and excessive siltation and sedimentation due to associated land-use practices.

The effect of reduced water quality relating to urbanisation in Sabie town should be negligible at this site due to the influx of numerous tributaries with high water quality conditions. This diluting effect could nullify the negative impact of reduce upstream water quality at this site. Element of tropical (Lowveld) fish distribution is expected during high flow at this site, while during the low flow period (winter) some of these species are absent migrating further downstream to temperate water.

The fish velocity depth classes recorded were **slow deep** (sparse to moderate), **fast shallow** (abundant) and **slow shallow** (sparse to abundant) with **fast deep** (abundant). The fish cover present identified was very abundant with very abundant overhanging vegetation and moderate undercut banks and root wads. A well developed riparian zone of indigenous tree spe cies was recorded. The substrate rated moderate in both the fast and slow fish velocity depth classes.

Fish assemblage

At this site fourteen of the twenty one expected fish species were recorded for the **high flow** and eleven of the expected species for the **low flow** surveys. The fish species were collected at relative abundance reflecting most of the age classes present – juveniles, sub-adults and adults. This can be related to a breeding function not disrupted at present.

The sensitive rheophylic species collected during the **high flow** surveys includes, *Opsaridium peringueyi, Barbus brevipinnis, Barbus eutaenia, Amphilius uranoscopus and Chiloglanis anoterus.* These species are flow dependant species with a high (4.3 to 4.6) flow-depth preference for fast deep and fast shallow fish velocity depth classes. All the species collected are totally in tolerant (4.6 to 4.8) to reduced flow conditions, have a very high (4.1 to 5) preference to substrate and is highly intolerant to water quality changes (4.7 to 4.8).

Marcusenius macrolepidotus, Petrocephalus catostoma, Barbus trimaculatus, Labeobarbus polylepis, Labeobarbus marequensis, Varicorhinus nelspruitensis, Labeo cylindricus, Micralestes acutidens and *Pseudocrenilabrus philander* are limnophylic species favouring sl ow flowing water, although during certain phases of life history stages a biotope of flowing water is required. Based on the intolerance rating these species are moderately tolerant to no flow conditions and modified water quality (physico-chemical).

Not all the expected fish species are present within this resource unit and the Frequency of Occurrence (FROC) of some species has been reduced from the reference condition s. The Frequency of

Occurrence (FROC) of the recorded species has furthermore been altered as a result of habitat deterioration due to excessive siltation and sedimentation and possibly reduced water quality conditions.

The CPUE (catch per unit effort) for the **high flow** is 8.1 (28 minute) and for the **low flow** 8.1 (30 minutes) which indicate a high abundance of recorded species during both the high and low flow periods. A Fish Response Assessmen t Index (FRAI) score of 81.1% was calculated for the **high flow** for this reach based on all available information, placing this reach in an Ecological Class B (slightly impaired with a high diversity of species). The Ecological class for the **low flow** based on FRAI is calculated at 78.4% and a B/C class (slightly impaired with a moderate diversity and abundance of species). The relative high ecological class B can be related t o habitat diversity and available fish habitat.

Impacts and mitigation

The fish assemblage present in this reach is impacted by sedimentation and siltation from a degraded catchment resulting in reduced available fish habitat. During the low flow period reduced water quality will also impact on the fish assemblage.

Table 6: Site 5 USM 2 – Brandwag: Species collected in different fish velocity-depth classes

USM 2 : Brandwag: X31D-00772														
Expected fish species Sabie Mainstem	Fish species collected		Total individuals		Juveniles		Sub adults		Adults		Slow deep	Slow shallow	Fast deep	Fast shallow
	High flow	Low flow	High flow	Low flow	High flow	Low flow	High flow	Low flow	High flow	Low flow				
Mormyridae														
Marcusenius macrolepidotus	X	X	7	4			X	X	X		3	4	3	0
Petrocephalus catostoma	X		5				X		X		3	4	3	0
Anguillidae														
Anguilla mossambica	X		1						X		0	0	0	4
Cyprinidae														
Mesobola brevianalis														
Opsaridium peringueyi	X		13				X		X		0	2	0	4
Barbus anoplus														
Barbus brevipinnis	X		7						X		0	2	2	4
Barbus unitaeniatus														
Barbus trimaculatus	X	X	9	16			X	X	X	X	0	0	4	4
Barbus eutaenia	X	X	23	32	X		X	X	X	X	0	2	2	4
Labeobarbus polylepis	X	X	11	28			X	X	X	X	2	2	3	4
Labeobarbus marequensis	X	X	22	6	X		X	X	X		2	2	3	4
Varcorhinus nelspruitensis		X		19				X		X	2	0	3	3
Labeo cylindricus	X	X	14	13			X	X	X	X	0	0	3	4
Characidae														
Micralestes acutidens	X	X	36	44			X	X	X	X	2	2	0	4
Amphiliidae														
Amphilius natalensis														
Amphilius uranoscopus	X	X	13	16			X	X	X	X	0	0	0	5
Clariidae														
Clarias gariepinus														
Mochokidae														
Chiloglanus anoterus	X	X	36	41	X		X	X	X	X	0	0	2	5
Cichlidae														
Pseudocrenilabrus philander	X	X	29	26	X		X	X	X	X	3	4	0	2
Tilapia sparrmanii														
Number of species	14	11												
Number of individuals			226	245										
CPUE for electric shocking	**High flow: 8.1 (28 minute)**				**Low flow: 8.1 (30minute)**									
Ecological class based on FRAI	**High flow: B class (81.1%)**				**Low flow: B/C class (78.4)**									

0 = absent 1=rare 2=sparse 3=moderate 4=abundant 5=very abundant

4.4. SQ Reach X31D-00755

Site 6 USM 1 – Aan de Vliet

General description

One monitoring sites USM 1- Aan de Vliet, X31D-00755 was selected to represent this reach. This reach is representative of the lower foothill stream, below 510 m.a.s.l., and is characterised as a low inclined, multiple channelled stream with some anastomosing and anabranching. The substratum is dominated by bedrock and contains multiple runs, some riffles and large pools. Within this catchment there is transformation to monoculture forestry and tropical fruit irrigation farming. The riparian vegetation is well-developed, consisting mainly of Mingerhout (*Breonadia microcephala*) providing additional habitat such as overhanging vegetation, root wads and undercut banks, and creates habitat for habitat specialists such as the Mormyridae. Moderate stands of alien invasive species occur in the riparian vegetation.

The fish velocity depth classes recorded were **slow deep** (sparse to moderate), **fast shallow** (very abundant) and **slow shallow** (sparse to abundant) with **fast deep** (moderate). The fish cover present identified was very abundant with very abundant overhanging vegetation and moderate undercut banks and root wads. A well developed riparian zone of indigenous tree species was recorded. The substrate rated moderate in both the fast and slow fish velocity depth classes.

Fish

This reach can be considered as a transitional zone between temperate and more tropical fish species with elements of both zones present. Fish species unique to the area include *Opsaridium peringueyi, Labeobarbus polylepis, Barbus eutaenia, Barbus argenteus, Chil oglanis anoterus* and the two Mormyrid fish species, *Marcusenius macrolepidotus, Petrocephalus catostoma.* At this site fifteen of the expected twenty six fish species were recorded for the **high flow** and fourteen species for the **low flow** surveys, all species were recorded in relative abundance.

The species diversity collected during the **high** and the **low flow** are very similar with the absence of Opsaridium *peringueyi* during the **low flow** period. During the surveys the sensitive rheophylic species collected includes, *Opsaridium peringueyi, Barbus eutaenia, Barbus argenteus, Amphilius uranoscopus, Chiloglanis anoterus and Chiloglanis paratus* . These species are flow dependant species with a high (4.3 to 4.6) flow-depth preference for fast deep and fast shallow fish velocity depth classes. All the species collected are totally intolerant (4.6 to 4.8) t o reduced flow conditions, have a very high (4.1 to 5) preference to substrate and is highly intolerant to water quality changes (4.7 to 4.8).

The limnophylic species favouring slow flowing water, although during certain phases of life history stages a biotope of flowing water is required, recorded during the surveys included *Marcusenius macrolepidotus, Petrocephalus catostoma, Barbus unitaeniatus, Barbus trimaculatus, Labe obarbus polylepis, Labeobarbus marequensis, Varicorhinus nelspruitensis, Labeo cylindricus, Labeo molybdinus, Micralestes acutidens,* and *Pseudocrenilabrus philander.* These species are moderately tolerant to no flow conditions and modified water quality (physico-chemical), based on the intolerance rating these species.

For most of the fish species all the age classes, juveniles, sub-adult and adult, were reflected indicating that the breeding function is functional. Not all the expected fish species are present within this resource unit and the Frequency of Occurrence (FROC) of some species has been reduced from the reference conditions. The Frequency of Occurrence (FROC) of the recorded species has furthermore been altered as a result of habitat deterioration due to siltation and sedimentation, as well as possible reduced water quality conditions.

The CPUE (catch per unit effort) for the **high flow** is 6.1 (34 minute) and for the **low flow** 6.7 (32 minutes) which indicate a high diversity and abundance of recorded species during both the **high** and **low flow** periods. A Fish Response Assessment Index (FRAI) score of 82.6% was calculated for the **high flow** and 80.1 % for the **low flow** for this reach based on all available information, placing this reach in an Ecological Class B (slightly impaired with a high diversity of species) for both the **high** and **low flow** periods. The relative high ecological class B can be related to habitat diversity and available fish habitat.

Impacts and mitigation

The fish assemblage present in this reach is impacted by sedimentation and siltation fro m a degraded catchment resulting in reduced available fish habitat. During the low flow period reduced water quality will also impact on the fish assemblage.

Table 7: Site 6 USM 1 – Aan de Vliet: Species collected in different fish velocity-depth classes

USM 1 : AandeVliet: X31D-00755														
Expected fish species Sabie Mainstem	Fish species collected		Total individuals		Juveniles		Sub adults		Adults		Slow deep	Slow shallow	Fast deep	Fast shallow
	High flow	Low flow	High flow	Low flow	High flow	Low flow	High flow	Low flow	High flow	Low flow				
Mormyridae														
Marcusenius macrolepidotus	X	X	9	5	X		X		X	X	3	4	3	0
Petrocephalus catostoma	X	X	6	3			X	X	X	X	3	4	3	0
Anguillidae														
Anguilla mossambica														
Cyprinidae														
Mesobola brevianalis														
Opsaridium peringueyi	X		15				X		X		0	2	0	4
Barbus anoplus														
Barbus brevipinnis														
Barbus unitaeniatus	X		4				X				0	2	2	4
Barbus trimaculatus	X	X	11	14			X	X	X	X	0	0	4	4
Barbus eutaenia	X	X	25	19			X	X	X	X	0	2	2	4
Barbus argenteus	X	X	8	14			X	X	X	X	0	2	3	4
Labeobarbus polylepis	X	X	5	15			X	X	X	X	2	2	3	4
Labeobarbus marequensis	X	X	24	3	X		X	X	X	X	2	2	3	4
Varicorhinus nelspruitensis		X		9				X		X	2	0	3	3
Labeo cylindricus	X	X	17	9			X	X	X	X	0	0	3	4
Labeo molybdinus	X	X	4	1			X		X	X	0	0	4	4
Characidae														
Micralestes acutidens	X	X	41	66	X		X	X	X	X	2	2	0	4
Amphiliidae														
Amphilius uranoscopus	X	X	3	14				X	X	X	0	0	0	5
Clariidae														
Clarias gariepinus														
Mochokidae														
Chiloglanus anoterus	X	X	24	31	X		X	X	X	X	0	0	2	5
Chiloglanus paratus	X	X	13	12			X	X	X	X	0	2	2	5
Chiloglanus swierstrai														
Cichlidae														
Pseudocrenilabrus philander	X	X	29	26	X		X	X	X	X	3	4	0	2
Tilapia sparrmanii														
Tilapia rendalli														
Oreochromis mossambicus														
Number of species	15	14	209	215										
Number of individuals														
CPUE for electric shocking	High flow: 6.1 (34 minute)				Low flow: 6.71 (32minute)									
Ecological class based on FRAI	High flow: B class (82.6%)				Low flow: B class (80.1%)									

0 = absent 1=rare 2=sparse 3=moderate 4=abundant 5=very abundant

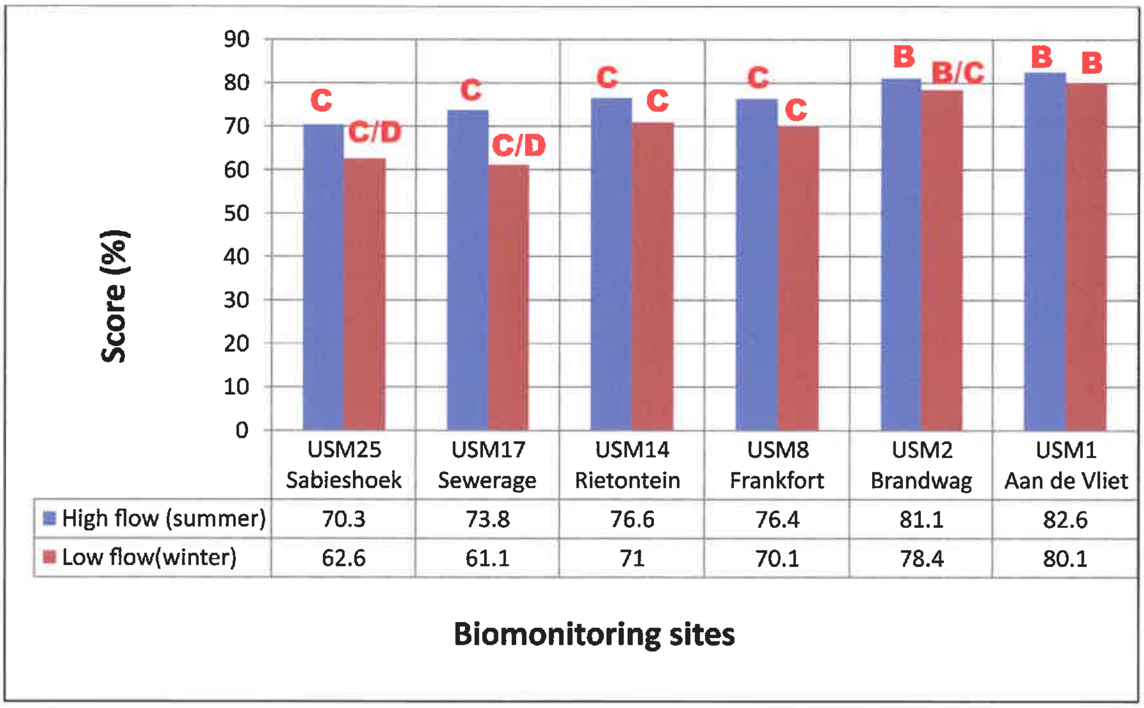
5. SUMMARY

From the combined graph (Figure 4) for the FRAI values and percentages obtained from this study for the high flow and low flow, it is evident that the upper reaches of the Sabie River is severely impacted by forestry activities, as well as urbanisation related impacts downstream of the town of Sabie. Furthermore of concern is the malfunctioning of the Sabie sewerage system.

At site 1, USM 25 Sabieshoek, the fish assemblage is impacted by introduced alien fish species (*Oncorhynchus mykiss*) which is stocked for recreational fishing. Due to forestry activities and extensive fires within the catchment 2007 excessive siltation and sedimentation results from a degraded catchment reducing available fish habitat. The low ecological class of a class C/D obtained for the low flow period (moderately to considerably impaired with a moderate diversity of taxa consisting mainly of tolerant species is of concern and mitigation measures need to be implemented.

The monitoring site USM 17, below the t own of Sabie and the sewerage works is largely impacted by urbanisation related impacts reducing water quality, as well as the forestry industry. At this site the reduced water quality is a result of the degraded habitat due to the forestry industry in the upper catchment.

This can also be ascribed for USM 14 and USM 8, where reduced water quality has an impact on the fish assemblage. In addition to this, the catchment has large ly been transformed to monoculture forestry resulting in excessive siltation and sedimentation reducing available fish habitat. Also to note, is that at USM 14 dissolved salts (EC) is still present further reducing water quality conditions. It is only at USM 2 and USM1 that the impact of Sabie town is negligible in terms of reduced water quality conditions. However, at both these sites tributaries feed a substantial amo unt of sediments into the mainstem as a result of forest related activities.



	USM25 Sabieshoek	USM17 Sewerage	USM14 Rietontein	USM8 Frankfort	USM2 Brandwag	USM1 Aan de Vliet
High flow (summer)	70.3	73.8	76.6	76.4	81.1	82.6
Low flow(winter)	62.6	61.1	71	70.1	78.4	80.1

Figure 4: Combined graph for the FRAI values of the biomonitoring sites in the Upper Sabie River for both the high and low flow periods.

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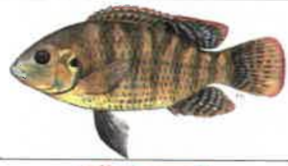
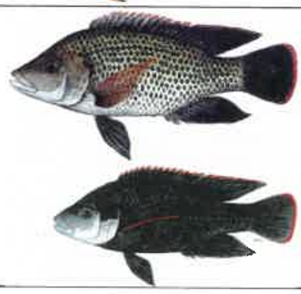
7. APPENDIX – Species collected at biomonitoring sites in the Upper Sabie River

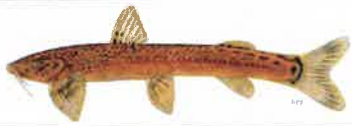
	USM 25 Sabieshoek	USM17 Sabie Sewerage	USM14 Rietfontein Mine	USM8 Frankfort	USM2 Brandwag	USM1 Aan de Vliet
Mormyridae						
Marcusenius macrolepidotus					X	X
Petrocephalus catostoma					X	X
Anguillidae						
Anguilla mossambica				X	X	
Cyprinidae						
Mesobola brevianalis						
Opsaridium peringueyi					X	X
Barbus anoplus	X			X		
Barbus brevipinnis					X	
Barbus unitaeniatus				X		X
Barbus trimaculatus					X	X
Barbus eutaenia					X	X
Barbus argenteus						X
Labeobarbus polylepis					X	X
Labeobarbus marequensis					X	X
Varicorhinus nelspruitensis		X	X	X		
Labeo cylindricus					X	X
Labeo molybdinus						X
Characidae						
Micralestes acutidens					X	
Amphiliidae						X
Amphillius natalensis	X	X	X			
Amphilius uranoscopus	X	X	X	X	X	X
Clariidae						
Clarias gariepinus						
Mochokidae						
Chiloglanus anoterus		X	X	X	X	X
Chiloglanus paratus						X
Chiloglanus swierstrai						
Cichlidae						
Pseudocrenilabrus philander				X	X	X
Tilapia sparrmanii	X	X	X	X		
Tilapia rendalli						
Oreochromis mossambicus						

8. APPENDIX – Photo's of Fish species

Illustrations of fish species from the Atlas of Southern African Freshwater Species - SAIAB (Scott et al., 2004) recorded at all the sampling sites .

FAMILY MORMYRIDAE - SNOUTFISHES	
Marcusenius macrolepidotus Bulldog	
Petrocephalus catostoma (wesselsi) Northern churchill	
FAMILY ANGUILLIDAE - FRESH WATER EELS	
Anguilla mossambica Longfin eel	
FAMILY CYPRINIDAE - BARBS, YELLOWFISH, LABEOS	
Mesobola brevianalis River sardine	
Opsaridium zambezense (perringuyei) Nothern barred minnow	
Barbus anoplus Chubbyhead barb	
Barbus brevipinnis Shortfin barb	
Barbus unitaeniatus Longbeard barb	
Barbus trimaculatus Three spot barb	
Barbus eutaenia Orange fin barb	
Barbus argenteus Rose fin barb	

FAMILY SALMONIDAE - TROUTS	
Salmo truta Brown trout	
Oncorhynchus mykiss Rainbow trout	
FAMILY CICHLIDAE - CICHLIDS	
Pseudocrenilabrus philander Southern mouth brooder	
Tilapia sparrmanii Banded tilapia	
Tilapia rendalli Red breast tilapia	
Oreochromis mossambicus Mozambique tilapia	

Labeobarbus polylepis Bushveld small scale yellowfish	
Labeobarbus marequensis Lowveld large scale yellowfish	
Varicorhinus nelspruitensis Incomati chisel mouth	
Labeo cylindricus Red eye labeo	
Labeo molybdinus Leaden labeo	
FAMILY CHARACIDAE - CHARACINS	
Micralestes acutidens Silver robber	
FAMILY AMPHILIIDAE - MOUNTAIN CATFISHES	
Amphilius natalensis Natal mountain catfish	
Amphilius uranoscopus Common or stargazer mountain catfish	
FAMILY CLARIIDAE - AIR-BREATHING CATFISHES	
Clarias gariepinus Sharptooth catfish	
FAMILY MOCHOKIDAE - SQUEAKERS, SUCKERMOUTH CATLETS	
Chiloglanis anoterus Pennant-tailed suckermouth or rock catlet	
Chiloglanis paratus Sawfin suckermouth or rock catlet	
Chiloglanis swierstrai Lowveld suckermouth or rock catlet	

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