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RIVER HEALTH PROGRAMME IN CROCODILE WEST MARICO WMA

TECHNICAL REPORT 3

FINAL

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ABBREVIATIONS

DWS	Department of Water & Sanitation
EI	Ecological Importance
EC	Ecological Category
ES	Ecological Sensitivity
EWR	Ecological Water Requirements
FROC	Fish Frequency of Occurrence
IHI	Index of Habitat Integrity
NAEHMP	National Aquatic Ecosystem Health Monitoring Programme
PES	Present Ecological State
REC	Recommended Ecological Category
RHAM	Rapid Habitat Assessment Method
RHP	River Health Programme
SoR	State of River
SQR	Sub-quaternary reach
WMA	Water Management Area

1 INTRODUCTION

1.1 OBJECTIVES OF THE STUDY

Healthy rivers provide various goods and services, which contribute to the social and economic growth of the surrounding communities and the Country as a whole. However, when people use rivers, they impact on the river health, which can lead to a state where the rivers are unsustainable and can no longer provide the values they once did.

The National River Health Programme (more recently renamed The River Ecostatus Monitoring Programme/ REMP) assesses the health of rivers by measuring selected ecological indicator groups that represent the condition of the larger riverine ecosystem. The data are simplified and represented as indices, while the overall ecological status of a river reach is expressed as the EcoStatus. The ecological importance and sensitivity ratings provide an indication of the relative ecological importance as well as its sensitivity to disturbances and therefore the level of protection that a river should receive.

With river health monitoring, problems can be identified at an early stage and prevention measures can be initiated before the problem becomes severe. In areas that are poor or unsustainable, intervention actions can be initiated in order to remedy and rehabilitate our vital water resources.

The Department of Water & Sanitation, North West Regional Office appointed Tlou Consulting to undertake the “River Health Programme in the Crocodile (West) Marico WMA” over the period April 2012 to March 2015. The contract was extended to July 2015.

1.2 OBJECTIVES OF THIS REPORT

This technical report presents the findings of the river health monitoring that was undertaken over the period October 2012 to March 2015. It also identifies the threats and impacts on the water resources of the WMA and provides management actions that are required to manage the rivers in a sustainable condition.

2 DELINEATION OF THE STUDY AREA

The Department of Water & Sanitation divided the Crocodile (West) Marico Water Management Area into seven (7) sub-areas for water resources planning purposes. The delineation was largely based on practical consideration such as size and location of sub-catchments, homogeneity of natural characteristics, location of dams and economic development.

Reporting on the River Health programme in this document will be in accordance with these seven sub-areas as indicated in Figure 2-1.

Each river reach was then defined based on physical aspects such as altitude, eco-region, geomorphic region and geology. Use was made of the DWS developed Sub-Quaternary Reach (SQR) framework for the purpose of delineating the rivers in the study area.

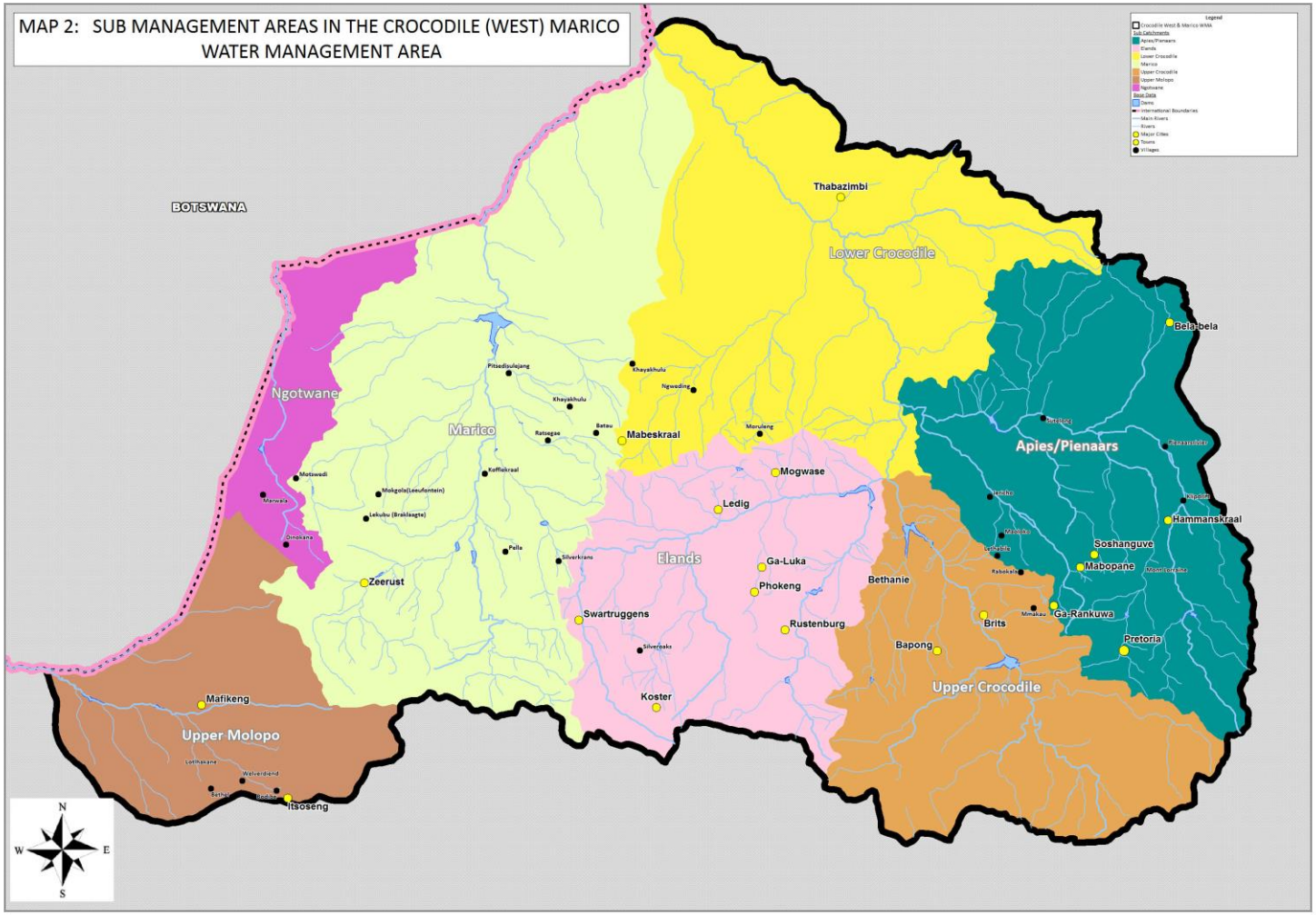


FIGURE 2-1. SUB-AREAS IN THE CROCODILE (WEST) MARICO WMA

3 OVERVIEW OF THE RIVER HEALTH PROGRAMME IN THE CROCODILE (WEST) MARICO WMA

This study considered existing RHP sites in the WMA and based on representativeness of the RHP site to the river reach and surrounding and upstream land use practices, sites were selected for further monitoring. The sites selected also considered other factors such as accessibility, availability of suitable habitat and historical information.

Eighteen River Health Monitoring sites were identified in the Crocodile River catchment and eight in the Marico River catchment. The Ngotwane and Molopo River catchments each had one River Health Monitoring site. These are listed in TABLE 3-1; **TABLE 3-2**; and TABLE 3-3 respectively.

Sampling for fish, macroinvertebrates and RHAM was conducted at these sites during 8 – 19 October 2012; 15 – 24 April 2013; 5 – 14 August 2013; 9-18 June 2014; 15-24 September 2014 and 2-11 March 2015. Riparian vegetation was sampled in April 2013, June 2014 and March 2015. Diatoms were sampled when suitable flow occurred at the site, i.e, in April 2013; August 2013 and June 2014.

For those reaches that were not covered by a RHP monitoring site, all available data was sourced, particularly from the records of NW-DEDECT, Ms H Roux and together with expert opinion, were assessed to provide the biological response categories and river reach Ecostatus. Extrapolation was not conducted for the river reaches in the Ngotwane and Molopo Rivers during this phase of the study. For SQRs where no relevant sites occur, Ecological Categories (ECs) were extrapolated using land use information, instream habitat information, geomorphic zone and ECs immediately upstream/downstream of the given reach as a guideline.

3.1 REPORTING FORMAT

Reporting on the River Health Programme in this document will be in accordance with these seven sub-areas as indicated in Figure 2-1 and the SQR framework developed by DWA. All data were integrated in RIVDINT (developed by Dr CJ Kleynhans, DWA - RQIS) for analyses and presentation of data and results.

TABLE 3-1. BIOMONITORING SITES IN THE CROCODILE RIVER CATCHMENT (PRIMARY A2)

SQ REACH	SITE CODE	RESOURCE NAME	LATITUDE	LONGITUDE
A21B-01135	A2HENN-HENNO	Hennops	-25,82603	27,98942
A21C-01167	A2JUKS-DIENR	Jukskei	-25,95390	27,96210
A21F-01116	A2MAGA-HARTE	Magalies	-25,86999	27,61498
A21H-01107	A2CROC-HARTB	Crocodile	-25,80040	27,89600
A21J-01053	A2CROC-MOUNT	Crocodile	-25,71680	27,84310
A21K-00959	A2STER-MAMOG	Sterkstroom	-25,59839	27,50575
A22A-01001	A2ELAN-KLIPB	Elands	-25,72656	26,72044
A22A-01001	A2ELAN-NOOIT	Elands	-25,58181	26,67822
A22E-00940B	A2ELAN-BESTE	Elands	-25,46392	26,78925
A22F-00845	A2ELAN-RIETS	Elands	-25,33489	27,29089
A22J-00878B	A2HEXR-ROOIW	Hex	-25,52136	27,37528
A23A-01056	A2PIEN-BAVIA	Pienaars	-25,66802	28,35099
A23B-00896	A2PIEN-DINOK	Pienaars	-25,40084	28,31269
A23F-00827	A2APIE-VASTF	Apies	-25,53736	28,23581
A23L-00706	A2PIEN-BUFFE	Pienaars	-25,13958	27,69114
A24C-00596	A2CROC-KOEDO	Crocodile	-24,88980	27,51833
A24H-00500	A2SAND-BRAKV	Sand	-24,68420	27,46900
A24J-00438	A2CROC-MAKOP	Crocodile	-24,40663	27,11545

TABLE 3-2. BIOMONITORING SITES IN THE MARICO RIVER CATCHMENT (PRIMARY A3)

SQ REACH	SITE CODE	SQR NAME	LATITUDE	LONGITUDE
A31A-0400	A3KAAL-RIETS	Kaaloog se Loop	-25,77700	26,43339
A31B-01039	A3GMAR-KOEDO	Groot-Marico	-25,65870	26,43500
A31D-00968	A3KARE-ABJAT	Kareespruit	-25,54147	26,10222
A31D-00968	A3KARE-RAILW	Kareespruit	-25,54147	26,10222
A32D-00539	A3GMAR-LOTTE	Marico	-24,84439	26,48600
A31F-00768	A3GMAR-STRAA	Groot-Marico	-25,31861	26,40100
A31B-00923/Groot-Marico B	A3GMAR-RIEKE	Groot-Marico	-25,46120	26,39189
A31B-00923/Groot-Marico A	A3GMAR-WONDE	Groot-Marico	-25,58903	26,41253

TABLE 3-3. BIOMONITORING SITES IN THE NGOTWANE AND MOLOPO RIVER CATCMENT (PRIMARY D4 AND A1)

SQ REACH	RIVER NAME	SQR NUMBER	Latitude	Longitude
A10A-00915	A10A-00915	NG01.00	25°51'12.40" E	25°27'20.29" S
D41A-01055	Molopo	MO02.00	25°26'59.59"E	25°51'33.29"S

The Ecological Importance (EI) and Ecological Sensitivity (ES) of the various river reaches were not determined during this study, however results from the recently completed PES/EI ES (Present Ecological State Ecological Importance & Ecological Sensitivity) study by DWA (DWA, 2013) were applied. The EI & ES of SQRs are assessed to obtain an indication of its vulnerability to environmental modification within the context of the PES. This would relate to the ability of the SQR to endure, resist and able to recover from various forms of human use (Kleynhans reference).

- EI refers to biophysical aspects in the SQR that relate to its capacity to function sustainably. EI does not refer to IUCN criteria which is addressed in the NFEPA approach, or issues related specifically to NFEPA principles to protect such biodiversity components.
- ES considers SQR attributes that relates to the sensitivity of biophysical components to general environmental changes such as flow, physico-chemical and geomorphic modifications.

4 METHODOLOGY

The general approach used for this study was based on the rapid appraisal methods recommended by the Department of Water & Sanitation in their guidelines for Resource Directed Measures for the Protection of Water Resources (DWA, 1999; Kleynhans & Louw, 2008) 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 variation 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 processes (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 is to use resident aquatic biota to characterize the existence and severity of impairments in the rivers of the Crocodile

(West) Marico WMA and to attempt to identify any sources and causes of impairment related to the catchment.

The RHP makes use of a suite of ecological indicators that have specifically been selected for their ability to integrate the impact of multiple disturbances on the state of rivers. The integration of the ecological indicators then provide information on the overall condition or health of the river, known as the ecological status (EcoStatus). This totality of the features and characteristics of the river and its riparian areas, manifests in its ability to support a natural array of species. This ability directly relates to the capacity of the system to provide a variety of goods and services.

For this report, data was collected primarily on habitat integrity and the biological response indicators shown in Figure 4-1.

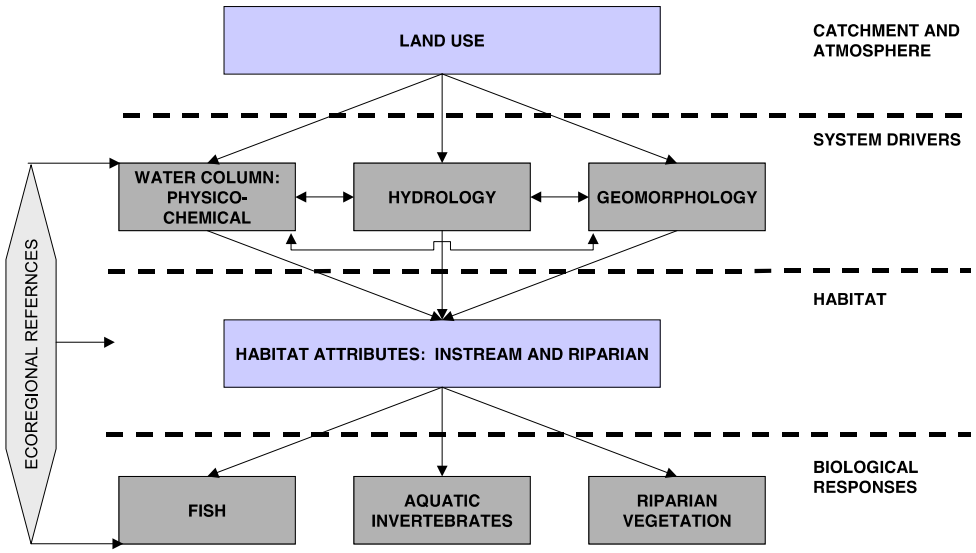


FIGURE 4-1. ECOLOGICAL STATUS ASSESSMENT (FROM KLEYNHANS & LOUW, 2008)

To achieve this, available water quality and flow data as well as an assessment of the geomorphological state of rivers were used in a qualitative way by experts in order to determine the habitat template to which the aquatic biota would respond. The integrated response of the habitat to modifications and the response of the biota to this, determines the health of the surveyed rivers. The outcome of this overall assessment will be referred to as the Ecostatus and comprises five indicators, namely:

- Habitat Integrity
    - Instream Habitat Integrity
    - Riparian Habitat Integrity
- Fish Assemblage Integrity
- Macro-invertebrate Integrity
- Riparian Vegetation Integrity

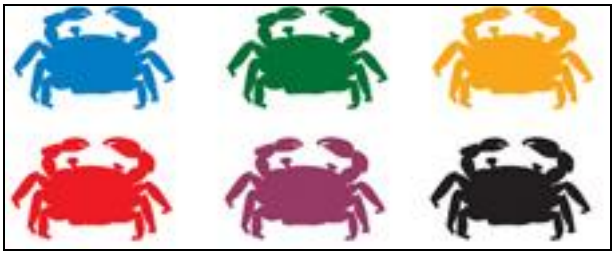
All raw data and specialist reports are available as appendices to this report. These have also been provided on CD.

The above data collected and analysed has been presented visually in the document, through a series of symbols, which are explained in **TABLE 4-1**.

TABLE 4-1. SYMBOLS USED TO PRESENT THE HABITAT AND BIOLOGICAL DATA COLLECTED

	Habitat Integrity
	Macro-invertebrate Integrity
	Fish Assemblage Integrity
	Riparian Vegetation Integrity
	Water Quality (Diatoms)

Colour-coding has further been used to describe the ecological category of the indicator. An example is provided in **FIGURE 4-2**:



Blue = Ecological Category A

Green = Ecological Category B

Yellow = Ecological Category C

Red = Ecological Category D

Purple = Ecological Category E

Black = Ecological Category F (Unsustainable)

FIGURE 4-2. EXPLANATION OF THE COLOUR-CODING USED IN THE MAPS

4.1 HABITAT INTEGRITY

The habitat integrity of a river refers to the maintenance of a balanced composition of physico-chemical and habitat characteristics on a temporal and spatial scale that are comparable to the characteristics of natural habitats of the region (Kleynhans 1996). Habitat integrity assessment is approached from an instream and riparian zone perspective and is seen as a surrogate for the assessment of biological responses to driver changes. It is also an integrated assessment of driver state (Kleynhans and Louw 2007). To accomplish this, information on abiotic changes that can potentially influence river habitat integrity are obtained from surveys or available data sources.

The Index of Habitat Integrity considers the severity of impacts on instream and riparian features such as the modification of the volume of water, a change in the flow regime (i.e. natural flow patterns), bed and channel modification, water quality, alien water plants, alien fauna that influences habitat directly and waste disposal. All of these impacts are considered in terms of their impact on the natural habitat features that would be expected for a particular type of river.

4.2 FISH ASSEMBLAGE

Fish are relatively long-lived and are good indicators of the longer-term changes in the condition of river habitats. These changes may be in response to alteration in river flows, changes in river structure or changes in the chemical composition of the water. Generally the fish assessment focuses on the integrity of the stream in terms of the fish fauna, and will consider possible impacts from the area and reach, and the possible effects it may have on the fish population.

4.2.1 SAMPLING

Sites were identified and surveyed, and the report will aim to categorise each reach according to the Fish Response Assessment Index (FRAI) used for River EcoClassification for South African Rivers (Kleynhans, 2007). The sites were selected to be representative of the river reach and all possible habitats representative of the site and river were. Observations and recommendations are made concerning the site, and the overall impacts in the area and reach, and also for the fish population.

The study area is visually surveyed on foot to identify and assess possible external impacts and different habitat types to obtain a comprehensive view of the study area. The assessed sites must be representative of a river in the sense that the habitat types distinctive of the river are available for sampling at the site.

Longitude and latitude coordinates are recorded with a Global Positioning System (GPS).

Fish are sampled using standard fish electro-shocking methods, and the abundance and diversity of the species are recorded for each habitat type and river segment sampled.

Fish ecological data is recorded i.e. species, lengths, maturity etc., to determine whether a healthy fish population exists. Lengths in general were recorded i.e. juveniles, mature and/or large specimens. Distinguishable length cohorts and the occurrence of smaller immature specimens may indicate whether spawning took place successfully during previous seasons. The external health of all fish sampled are observed and recorded.

4.2.2 ANALYSIS

A qualitative assessment of the fish assemblage integrity is undertaken as described by Kleynhans (1999), Kleynhans and Engelbrecht (2001), and Kleynhans (2007), (FRAI). The FRAI is an integration of the integrity of the fish assemblage based both on actual sampling and an interpretation of the habitat potential (i.e. available habitat at the site and in the reach).

The FRAI is done to assess the FROC of fish species, the PES and EC. The reference fish assemblage composition and frequency of occurrence was determined using a procedure developed by Kleynhans (*Pers.comm.* 2013) for each secondary catchment and Sub-Quaternary reach based on the PESEIS assessment and the FROC.

4.3 AQUATIC MACROINVERTEBRATES

Macroinvertebrate communities are good, short-term, biotic indicators of integrated stressors on river resources. Macroinvertebrate community composition and abundance can be impacted due to flow alterations, habitat disturbance and water quality perturbations, or any combination of these stressors. Macroinvertebrates possess various sensitivities to these three system drivers thereby giving an indication of the overall disturbance to the ecological integrity of a freshwater resource.

4.3.1 SAMPLING

Sampling was conducted according to the SASS5, the South African Scoring System Version 5 method, which is a rapid biomonitoring tool that was developed for lotic (flowing water) systems only. The method assesses macroinvertebrate communities occupying different instream habitats and uses pre-determined sensitivity weightings assigned per taxon. Macroinvertebrates are identified mostly to family taxonomic level. The method gives an indication of water quality impairment and overall river integrity/health. Detail on the method can be obtained from Dickens and Graham, 2002.

4.3.2 ANALYSIS

The MIRAI (Macroinvertebrate Response Assessment Index) was used to analyse the SASS5 data collected. Present day, as well as relevant, historic data for sites within the relevant SQR (Sub-quaternary reaches) were sourced. MIRAI was developed to provide a habitat-based cause-and-effect foundation to interpret the deviation of the macroinvertebrate assemblage from reference condition (Thirion, 2007). The MIRAI generates an Ecological Category (EC) for macroinvertebrates by integrating the ecological requirements of an assemblage and relating this to modified flow, instream habitat and water quality conditions. An EC was derived per SQR within which relevant sites for this project are located. Reference conditions for this project were set by using historic SASS5 data, as well as specialist judgement. Frequencies of Occurrence (FROCs) were set using the SASS5 data. For SQRs where no relevant sites occur, ECs were extrapolated using land use information, instream habitat information, geomorphic zone and ECs immediately upstream/downstream of the given reach as a guideline.

4.4 RIPARIAN VEGETATION

VEGRAI is designed for qualitative assessment of the response of riparian vegetation to impacts in such a way that qualitative ratings translate into quantitative and defensible results. This considers

the severity of impacts on riparian features such as the modification of the volume of water, a change in the flow regime (i.e. natural flow patterns), channel modification, water quality, reduction in vegetation and invasion by alien plants. All of these impacts are considered in terms of their impact on the natural riparian habitat features that would be expected for a particular type of river. The assessment of the riparian vegetation was done according to the Level 3: Riparian Vegetation Response Assessment Index (VEGRAI) (Kleynhans, Mackenzie, & Louw, 2007)

4.4.1 SAMPLING

According to the VEGRAI Level 3 index, the following components are assessed: site extent determination, site delineation, hydro-geomorphic zone determination, vegetation species lists, land-use and impact evaluation, exotic vegetation species and its invasion (Kleynhans, Mackenzie, & Louw, 2007).

4.4.2 ANALYSIS

The metrics in VEGRAI first describe the status of riparian vegetation in both its current and reference states and second, compare differences between the two states as a measure of vegetation response to an impact regime. The riparian vegetation zones (Marginal, Lower and Upper) were used as the metric groups. For the Level 3 version, the Lower and Upper zones were combine to form the Non-Marginal metric group (zone).

A range of metrics for each metric group was selected of which some are essential for both Levels 3 and 4 (Abundance and Cover) and the others are optional. The metrics are then rated and weighted and an Ecological Category (A-F) determined, which represents the Ecological Category for the riparian vegetation state.

4.5 DIATOMS

In this study diatoms were used to support the assessment of water quality.

Diatoms are the unicellular algal group most widely used as indicators of river and wetland health as they provide a rapid response to specific physico-chemical conditions in the water and are often the first indication of change. The presence or absence of indicator taxa can be used to detect specific changes in environmental conditions such as eutrophication, organic enrichment, salinization and changes in pH. They are therefore useful for providing an overall picture of trends within an aquatic system.

In this study the category for water quality was based solely on human landuse impacts such as intensive agriculture or mining, as animal related impacts have remained generally consistent throughout history in the area. Therefore animal associated impacts were not factored in when determining the Ecological Category for these sites. The animal impacts however are factored in the IHI, in terms of bed modification (trampling, sedimentation, etc.) and enrichment as well as the riparian IHI (vegetation removal due to grazing, etc.)

4.6 RIVER HEALTH CATEGORIES

A river health categorisation is used to provide a simplified user-friendly key to a much more intricate and complex process of assessing the EcoStatus of a river. Each river health category relates to a level

of ecosystem health, which in turn relates to the potential of the river to support a particular range of ecosystem services, as presented in Table 4-2.

TABLE 4-2. RIVER HEALTH CATEGORIES (MODIFIED FROM KLEYNHANS AND LOUW (2008))

ECOLOGICAL CATEGORY	DESCRIPTION	SCORE (% OF TOTAL)
A	Unmodified, natural.	90-100
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.	80-89
C	Moderately modified. Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.	60-79
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.	40-59
E	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive.	20-39
F	Critically / Extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.	0-19

5 RESULTS IN THE UPPER CROCODILE SUB-AREA

This area corresponds to the catchment of the Crocodile River upstream of the confluence of the Elands River (Figure 5-1). Main rivers and tributaries in this catchment include the Sterkstroom, Magalies, Skeerpoort, Rosespruit, Kareespruit, Crocodile, Jukskei, Klein Jukskei and Hennops rivers. The Crocodile River has its source in the Witwatersrand mountain range at a height of 1 700 m.a.s.l. The northern suburbs of Johannesburg, as well as parts of adjacent cities such as Kempton Park and Krugersdorp are situated in this sub-catchment. There are two large dams in this sub-catchment, namely the Hartbeespoort and Roodekopjes Dams. The upper reaches of the catchment are densely populated .

5.1 RIVER HEALTH MONITORING SITES IN THE UPPER CROCODILE SUB-AREA

Six monitoring sites were selected in the Upper Crocodile River sub-area. These sites are representative of the reaches in which they are located. Table 5-1 provides the sub-quaternary reaches within the Upper Crocodile Sub-Area and the River Health Monitoring Sites that have been sampled over the project period.

TABLE 5-1. SUB-QUATERNARY REACHES AND RIVER HEALTH MONITORING SITES IN THE UPPER CROCODILE SUB-AREA

MONITORING SITE	SQR REACH	RIVER NAME	SQR NUMBER	LATITUDE	LONGITUDE
	A21E-01224	Crocodile	C01.00		
	A21E-01162	Crocodile	C02.00		
	A21H-01158	Crocodile	C03.00		
	A21A-01171	Hennops	C03.01		
A2HENN-HENNO	A21B-01135	Hennops	C03.03	-25.82603	27.98942
A2CROC-HARTB	A21H-01107	Crocodile	C04.00	-25.80040	27.89600
	A21H-01112	Crocodile	C05.00		
A2CROC-MOUNT	A21J-01053	Crocodile	C07.00	-25.71680	27.84310
	A21J-01011	Crocodile	C08.00		
	A21J-00989	Crocodile	C09.00		
	A21J-00976	Crocodile	C10.00		
	A21J-00921	Crocodile	C11.00		
	A21L-00853	Crocodile	C12.00		
	A21C-01269	Jukskei	J01.00		
	A21C-01232	Jukskei	J02.00		
	A21C-01215	Jukskei	J03.00		
	A21C-01183	Jukskei	J04.00		
A2JUKS-DIENR	A21C-01167	Jukskei	J05.00	-25.95390	27.96210
	A21F-01208	Magalies	M01.00		
	A21F-01168	Magalies	M02.00		
A2MAGA-HARTE	A21F-01116	Magalies	M03.00	-25.86999	27.61498
	A21H-01097	Magalies	M04.00		
	A21K-01124	Sterkstroom	ST01.00		
	A21K-01023	Sterkstroom	ST02.00		
A2STER-MAMOG	A21K-00959	Gwathle	ST03.00	-25.59839	27.50575

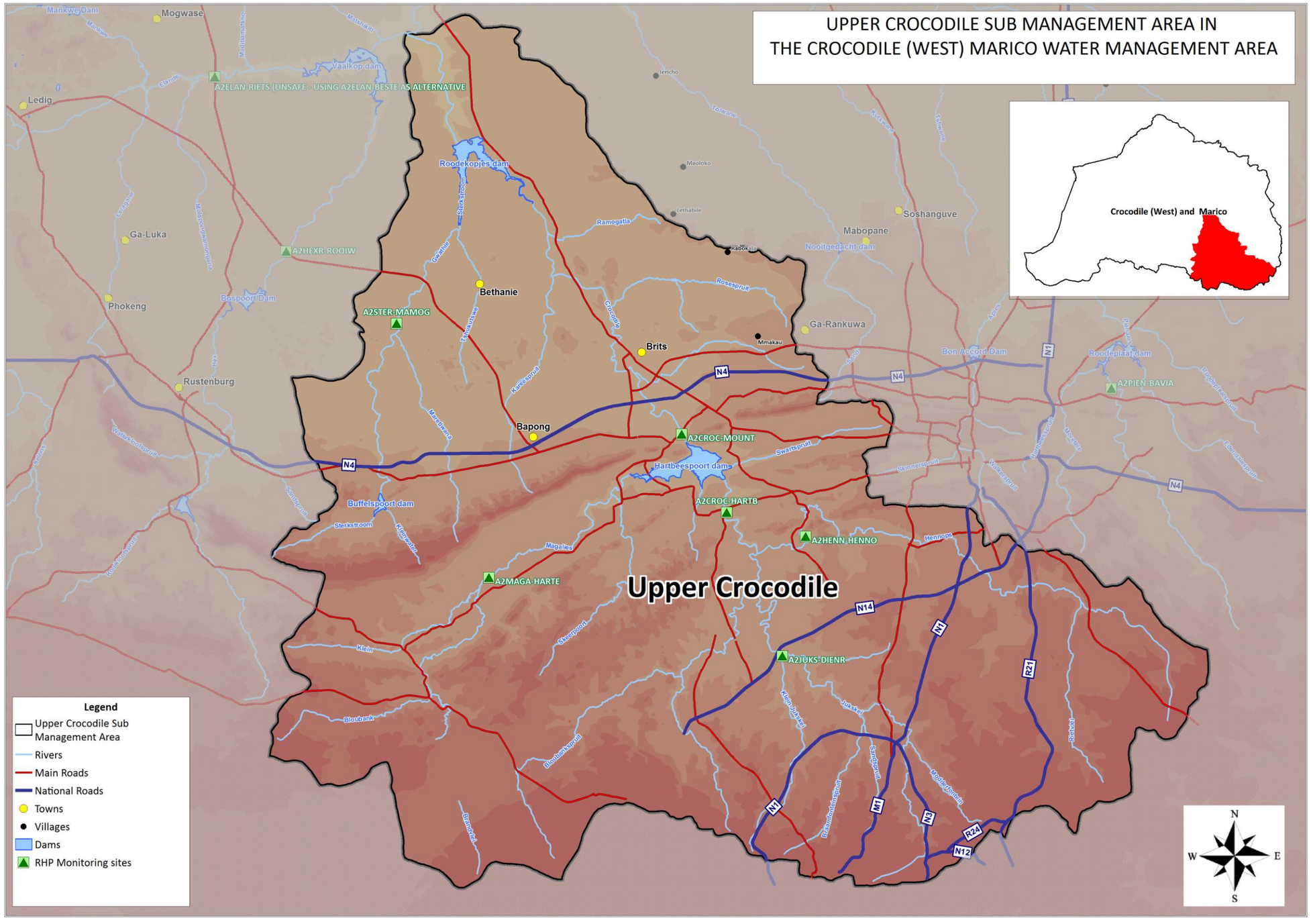


FIGURE 5-1. OVERVIEW OF THE UPPER CROCODILE SUB-MANAGEMENT AREA

5.2 ECOLOGICAL HEALTH OF THE UPPER CROCODILE RIVER

The overall ecological health of the Upper Crocodile River is largely modified (Figure 5-3). It can be seen that the condition of the river deteriorates as it flows further into the sub-area, due to various land-use activities. There is a large loss of natural habitat, biota and basic ecosystem functions. The river is in a D ecological state. The sites monitored, namely A21H-01107 (in SQR A2CROC-HARTB) and A21J-01053 (in SQR A2CROC-MOUNT) (Figure 5-2) show a steady decline in ecological condition over the 3 years of sampling.

Assessment of the other sub-quaternary reaches was based on a desktop analysis of the Habitat Integrity, using Google Earth imagery. Being a desktop analysis, it was not sensitive enough to pick up deterioration in ecological health within the ecological category of D.

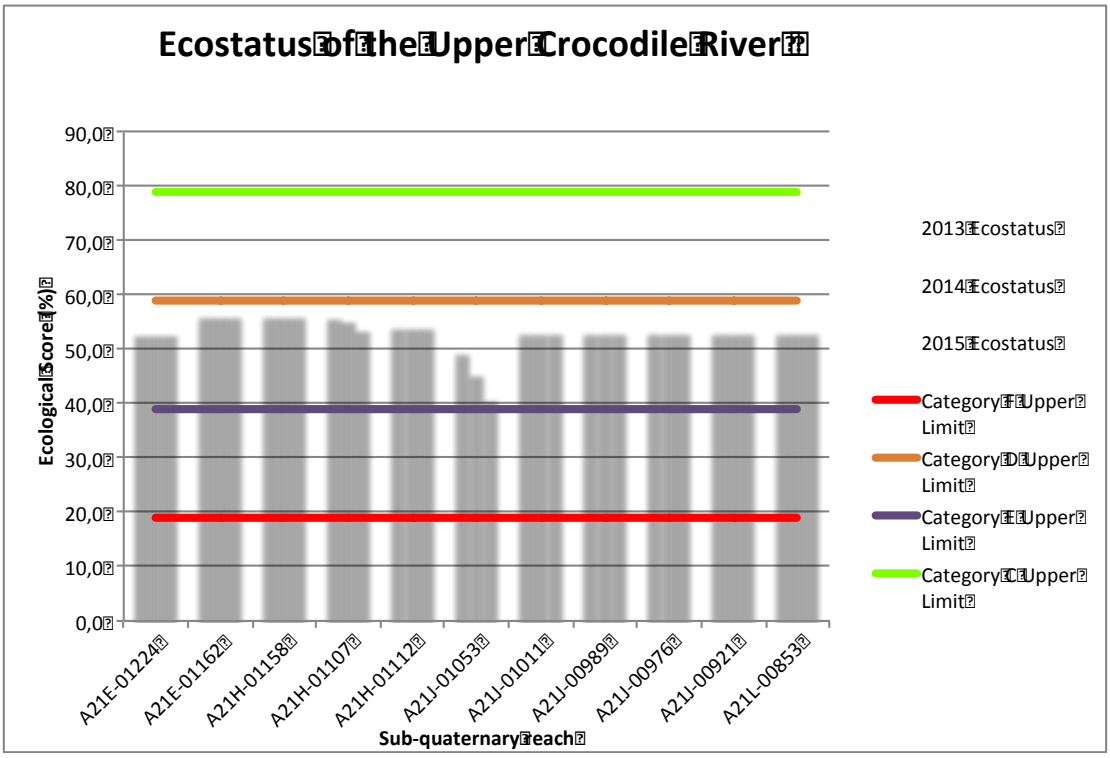


FIGURE 5-2. ECOSTATUS OF THE UPPER CROCODILE RIVER FROM UPSTREAM (LEFT) TO DOWNSTREAM (RIGHT)

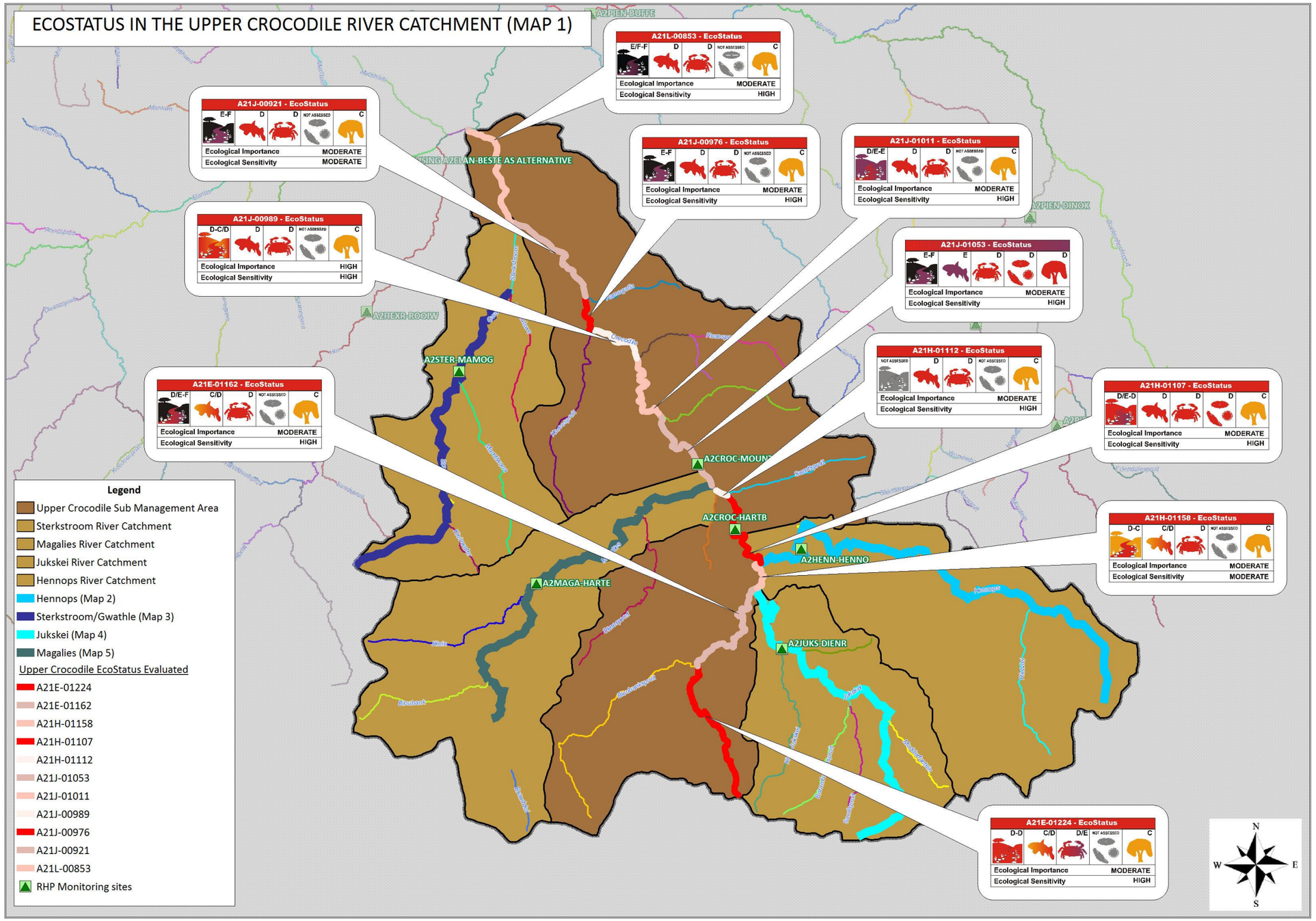


FIGURE 5-3. ECOLOGICAL STATE OF THE UPPER CROCODILE RIVER CATCHMENT

An assessment of the biota and instream conditions was conducted at the 2 monitoring sites. The results are shown in Figure 5-4 - Figure 5-7. From these figures it is clear that the biological condition of the river is consistently deteriorating . The fish in particular show a marked decline, particularly at the reach downstream of the Hartebeespoort Dam (A21J0-1053). The instream condition is bordering on unsustainable. Indications are that it is seriously modified, with extensive loss of natural habitat, biota and basic ecosystem functions.

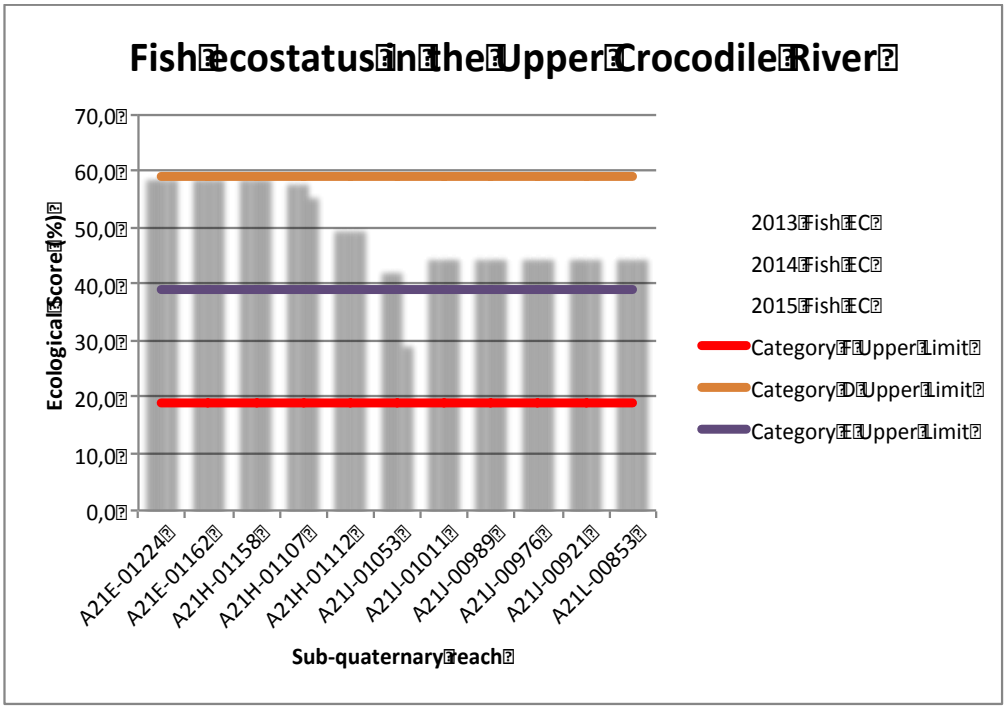


FIGURE 5-4. ECOLOGICAL STATE OF THE FISH IN THE UPPER CROCODILE RIVER

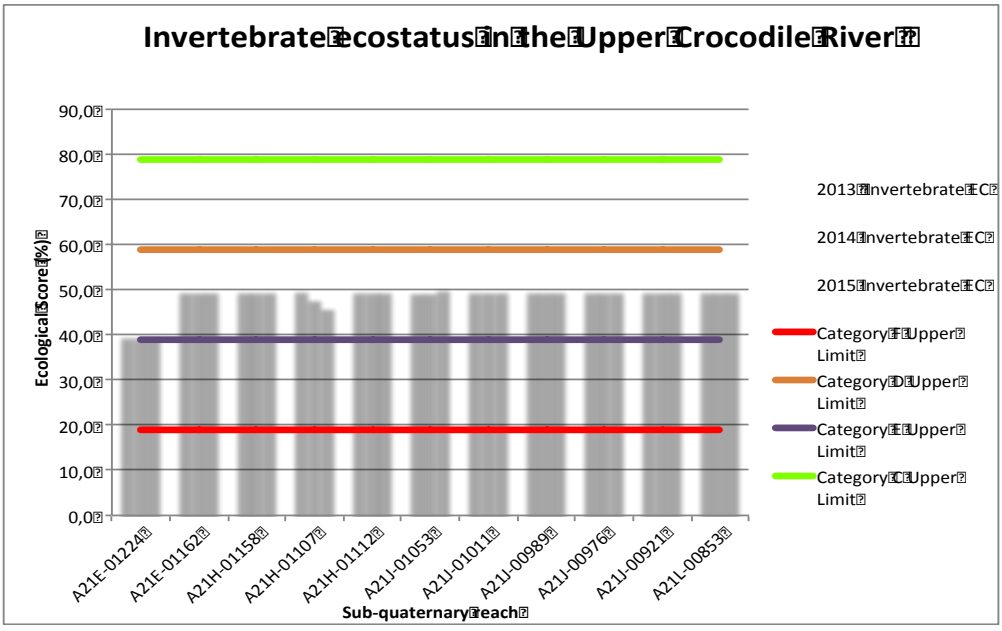


FIGURE 5-5. ECOLOGICAL STATE OF THE MACRO-INVERTEBRATES IN THE UPPER CROCODILE RIVER

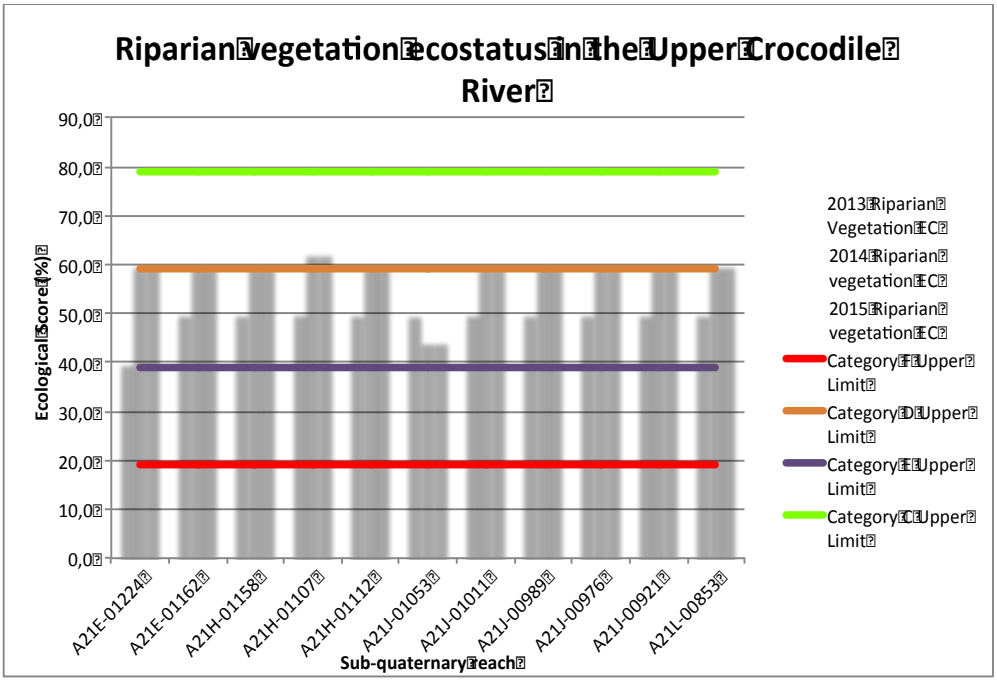


FIGURE 5-6. ECOLOGICAL STATE OF THE RIPARIAN VEGETATION IN THE UPPER CROCODILE RIVER

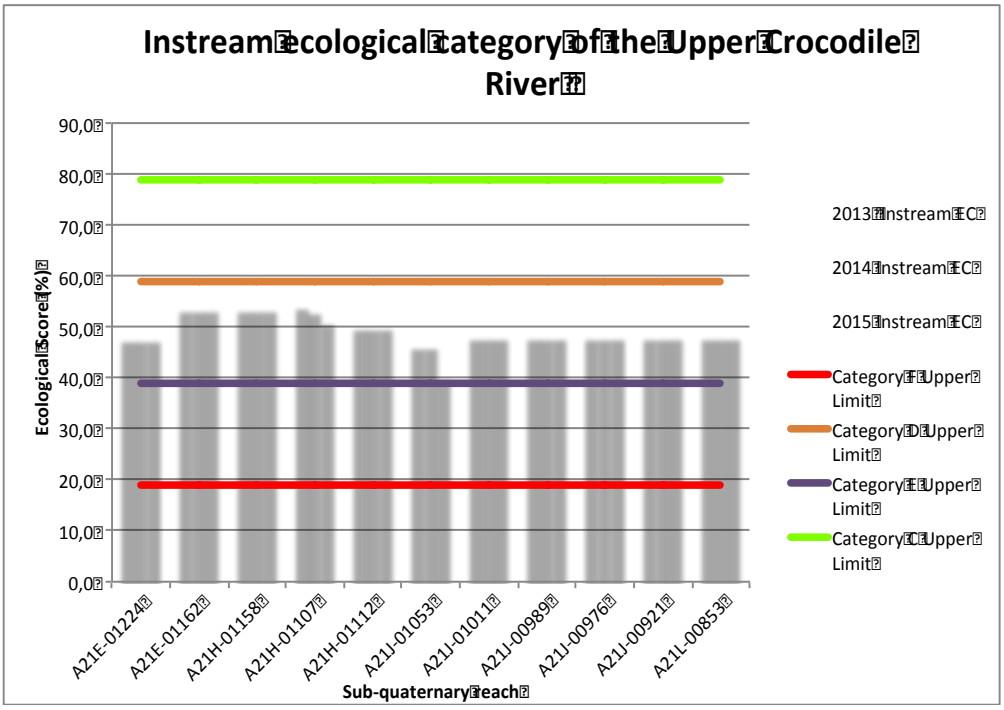


FIGURE 5-7. INSTREAM ECOLOGICAL HEALTH IN THE UPPER CROCODILE RIVER

5.2.1 MONITORING RESULTS: REACH A21H-01107 (REPRESENTED BY A2CROC-HARTB)

	
August 2013	June 2014
	
March 2015	March 2015

FIGURE 5-8. SITE A2 CROC-HARTB (A21H-01107)

GENERAL DESCRIPTION

This site is situated approximately 480m upstream of the R104, before the Crocodile River enters the Hartbeespoort Dam. Land use in the reach is predominantly open areas, with larger plots of open land and associated homesteads. There are numerous weirs in the reach, however none in close vicinity of the site. Upstream agriculture and urbanisation has impacted this reach. Immediate land use consists of homesteads with recreational fishing and swimming occurring at the site. Litter is present, with a dirt track situated next to the site. Bank erosion and exotic vegetation is also present at the site. .

FISH

The site was surveyed during August 2013; June 2014 and March 2015 with a fish-electro shocker. During the other surveys (April 2013 and September 2014) visual assessments were done due to high

flows. Fish were not sampled during April 2013 due to high flow. Turbidity and high flow condition made sampling impossible – fish cannot be seen and is washed away with electro-shocking.

The PES: EC varied from 2013 to 2014 (58.2% C/D) to 2015 (55.8% D), indicating a negative trend. The main reasons for the reduced PES EC for fish are constant high flows, reduced water quality (pollution upstream from Gauteng area), sedimentation and embedding of substrate.

All the expected fish species are expected to still be present within this SQ Reach although the Frequency of Occurrence (FROC) of some species has been reduced slightly from reference conditions.

There will be a long term negative trend in the fish species PES due to the presence of an alien fish species *Cyprinus carpio*, *Micropterus salmoides* and *Gambusia affinis* which have a negative impact in native fish species.

Species with a preference for substrate (rocks and rocky habitat etc.) received reduced FROC's, as there is siltation/sedimentation and algal growth present at the site. Enrichment also plays a role in the abundance and occurrence of species. Urban and agricultural run-off and water pollution will also influence the FROC's of species intolerant to water quality modification.

Flow modification, due to dams, weirs and abstraction result in loss of habitat and substrate quality; increased sedimentation and embedded substrate and loss of flow depth classes and habitat cover, affecting the species composition and lead to species loss. Dams and weirs will also influence species migration.

MACROINVERTEBRATES

Five data sets were used to run the MIRAI to derive an EC, with data from 2007 to 2015. Changes to the macroinvertebrate include negative impacts to the flow, habitat and water quality, with water quality being severely modified. Specific changes include frequency of occurrence and/or abundance of taxa with a moderate as well as those with a low requirement for unmodified physico-chemical conditions.

RIPARIAN VEGETATION

The riparian vegetation was found to be in a D condition, with a negative trend.

Marginal Zone

Grass and reed (including some sedges) dominated state. This zone is scoured with little vegetation cover; *Paspalum distichum*, *Phragmites australis, Typha capensis* and *Cyperus sexangularis* occur in clumps, with *Equisetum ramosissimum* growing densely in places. Individual *Combretum erythrophyllum* and *Salix mucronata* occur. The dominant substrate is soil, bedrock, boulders, rocks and pebbles. Impacts comprise the dam wall upstream, road crossing, bank erosion, flooding, exotic vegetation and the footprint of the holiday resort. It is suspected that, due to flooding, the exotic hydrophytic species *Eichhornia crassipes* has been washed away. The effect of armouring on the right bank is visible.

Non-marginal Zone

Tree and grass dominate, with forbs also present. There is little shrub cover. The non-woody component consists mainly of grass and forbs. Grasses such as *Panicum coloratum, Imperata cylindrica, Cynodon dactylon, Pennisetum clandestinum,* etc. are present. The woody species dominating include *Salix mucronata*, *Ficus sur, Searsia lancea*, *Diospyros lycioides, Croton gratissimus, Ziziphus mucronata, Rhamnus zeyheri, Acacia xanthophloea, Acacia karroo, Acacia galpinii, Combretum erythrophyllum*, etc. There is reasonable tree cover on the left bank. Good tree and shrub cover occur on the right bank. Alien invader species include *Melia azedarach, Salix babylonica, Melilotus albus, Ageratina adenophora, Phytolacca octandra, Datura stramonium, Xanthium strumarium*, etc. This zone consists of several terraces, some of which are artificial. Bank substrate consists of dumped material, rocks, bedrock, soil, etc. Bank scouring has resulted in steep, eroded banks in places. There is an indirect impact from the holiday resort, with the armouring effect of the dam wall upstream also visible.

WATER QUALITY

Diatom analysis indicates poor water quality in this reach, equivalent to that of a category D.

The site has a high abundance of *Navicula cryptotenella*, a taxon which has been associated with agricultural impacts. The site shows signs of some industrial disturbances due to the presence of *Fragilaria capucina var. capucina*, *Fragilaria capucina var.vaucheriae* and *Fragilaria fasciculata*, taxa often associated with industrial effluent. Other dominant species present are often found in strongly organically polluted, eutrophic, electrolyte-rich rivers, such as *Eolimna subminuscula*, *Navicula gregaria* and *Sellaphora seminulum.* Also present is dominant taxon *Diatoma vulgaris* which may point to elevated levels of phosphate-phosphorus.

5.2.2 MONITORING RESULTS: REACH A21J-01053 (REPRESENTED BY A2CROC-MOUNT)

	
August 2013	September 2014

	
March 2015	March 2015

FIGURE 5-9.SITE A2 CROC-MOUNT (A21J-01053)

FISH

Fish surveys were conducted during August 2013, June and September 2014, and March 2015. A change in the PES and EC was observed from 2013-2014-2015.

The PES and EC was stable at 42.6%/D for 2013-2014, but was reduced during March 2015 due to bass being sampled (29.6% E). High numbers of fish were recorded during 2014 and 2015 although the species diversity was low. Two species were sampled during 2013 and 2014 (*Labeobarbus Marequensis* and *Pseudocrenilabrus Philander*). High numbers of certain fish species were recorded during the March 2015 fish survey. The fish sampled during March 2015 were mostly hardy species with their fry and juveniles (Bass (*Micropterus salmoides*), *Pseudocrenilabrus Philander, Oreochromis Mossambicus, Chetia Flaviventris Trewavas, Tilapia Sparrmanii*, and *Labeobarbus Marequensis*). *Pseudocrenilabrus Philander* and *Oreochromis Mossambicus* were sampled in the thousands – mostly juveniles.

The major decline in PES and EC is described to the presence of bass (*Micropterus salmoides*).

All the expected fish species are expected to still be present within this SQ Reach although the Frequency of Occurrence (FROC) of some species has been reduced from reference conditions. Species with a preference for substrate (rocks and rocky habitat etc.) received reduced FROC's, as there is extensive algae growth present at the site (*Labeobarbus Marequensis, Chiloglanis Pretoriae, Labeo Cylindricus,* and *Labeo Molybdinus*). Enrichment also plays a role in the abundance and occurrence of most species and influenced the FROC's of species, which are intolerant to moderately intolerant to WQ modification (see above). Water enrichment, pollution from upstream areas, industry, agriculture and mines will also influence the FROC's of species intolerant to water quality modification.

Large dams, weirs, and water abstraction (flow modification) leading to low water levels and fewer events for flushing sediments will result in habitat deterioration and species loss. Dams, weirs and low water levels also influence species migration negatively. Flow modification, in this case low flows, results in poor habitat quality, poor water quality, loss of habitat integrity, and possible loss of species.

A negative trend will continue for the fish if above impacts are not addressed.

MACRO-INVERTEBRATES

Seven data sets were used to run the MIRAI to derive an EC, with data from 2007 to 2015. Minor changes took place, with the site remaining stable and in a D category.

Taxa with a high requirement for unmodified physic-chemical conditions are completely absent, whilst those with a moderate requirement for unmodified physic-chemical conditions are mostly absent, with those that do occur at a lower frequency of occurrence and abundance than expected under natural conditions. Taxa with a preference for fast flowing and moderately fast flowing water are highly impacted. Perlidae, Tricorythidae, Psephenidae and >2spp Hydropsychidae are completely absent in this reach. The presence of taxa that show preference for loose cobbles is highly impacted, as well as the presence of taxa that show a preference for marginal vegetation and GSM (gravel, sand and mud).

RIPARIAN VEGETATION

The present state of the Riparian vegetation was found to be in a category D with a negative trend.

Marginal Zone

Grass and reed (including some sedges) dominated state. This zone is scoured, with little vegetation cover; *Paspalum distichum*, *Phragmites australis, Typha capensis* and *Cyperus sexangularis* occur in clumps, with *Equisetum ramosissimum* growing densely in places. Individual *Combretum erythrophyllum* and *Salix mucronata* occur. The dominant substrate is soil, bedrock, boulders, rocks and pebbles. Impacts comprise the dam wall upstream, road crossing, bank erosion, flooding, exotic vegetation and the footprint of the holiday resort. It is suspected that, due to flooding, the exotic hydrophytic species *Eichhornia crassipes* has been washed away. The effect of armouring on the right bank is visible.

Non-marginal Zone

Tree and grass dominated state with forbs. There is little shrub cover. The non-woody component consists mainly of grass and forbs. Grasses such as *Panicum coloratum, Imperata cylindrica, Cynodon dactylon, Pennisetum clandestinum,* etc. are present. The woody species dominating include *Salix mucronata*, *Ficus sur, Searsia lancea*, *Diospyros lycioides, Croton gratissimus, Ziziphus mucronata, Rhamnus zeyheri, Acacia xanthophloea, Acacia karroo, Acacia galpinii, Combretum erythrophyllum*, etc. There is reasonable tree cover on the left bank. Good tree and shrub cover occur on the right bank. Alien invader species include *Melia azedarach, Salix babylonica, Melilotus albus, Ageratina adenophora, Phytolacca octandra, Datura stramonium, Xanthium strumarium*, etc. This zone consists of several terraces, some of which are artificial. Bank substrate consists of dumped material, rocks, bedrock, soil, etc. Bank scouring has resulted in steep, eroded banks in places. There is an indirect impact from the holiday resort, with the armouring effect of the dam wall upstream also visible

WATER QUALITY

Site A2 Croc-Mount was assigned a category D (Poor quality) as reflected by the presence of dominant taxa *Nitzschia palea* and *Amphora veneta*, found in nutrient enriched and very heavily to extremely polluted waters with an elevated electrolyte content.

5.2.3 IMPACTS, THREATS AND MANAGEMENT PRIORITIES IN THE UPPER CROCODILE RIVER

The main impacts resulting in loss of ecological health include:

- Large dams and water abstraction, resulting in flow alteration and loss of habitats
- Decreased water quality due to land use practices, resulting in loss of habitat and species. Nutrient enrichment causing algal growth is also promoting a loss of habitat.

Management intervention is necessary to prevent further degradation of the ecological health and sustainability of the river. Management priorities include:

- Management of land use activities, such as mining, agriculture, urbanisation and point-source discharges into the water resource
- Ensure minimum flow releases from the dam to flush sediments and prevent algal growth
- Management of minimum flow conditions, by implementing the ecological flow requirements that have been established by the DWS.

5.3 ECOLOGICAL HEALTH OF THE HENNOPS RIVER

The overall ecological health of the Hennops River, from its source to the confluence with the Crocodile River, is largely modified. It is in a low D ecological category (Figure 5-10). There is a large loss of natural habitat, biota and basic ecosystem functions. The site assessed , namely A21B-01135 (A2HENN-HENNO) indicates a relatively stable ecological condition over the last two years of monitoring (**Error! Reference source not found.**)?. This site was assessed at a tertiary level of assessment, i.e. visual observations only were made.

The poor condition of the river is due to land-based activities, predominantly urbanisation and discharges from the Sunderland Ridge Wastewater Treatment Works. The assessment of the sub-quaternary reach A21A-01171 was based on a desktop analysis of the Habitat Integrity, using Google Earth imagery, while assessment over the 3-year period was conducted at site A2HENN_HENNO, which represented sub-quaternary reach A21B-01135.

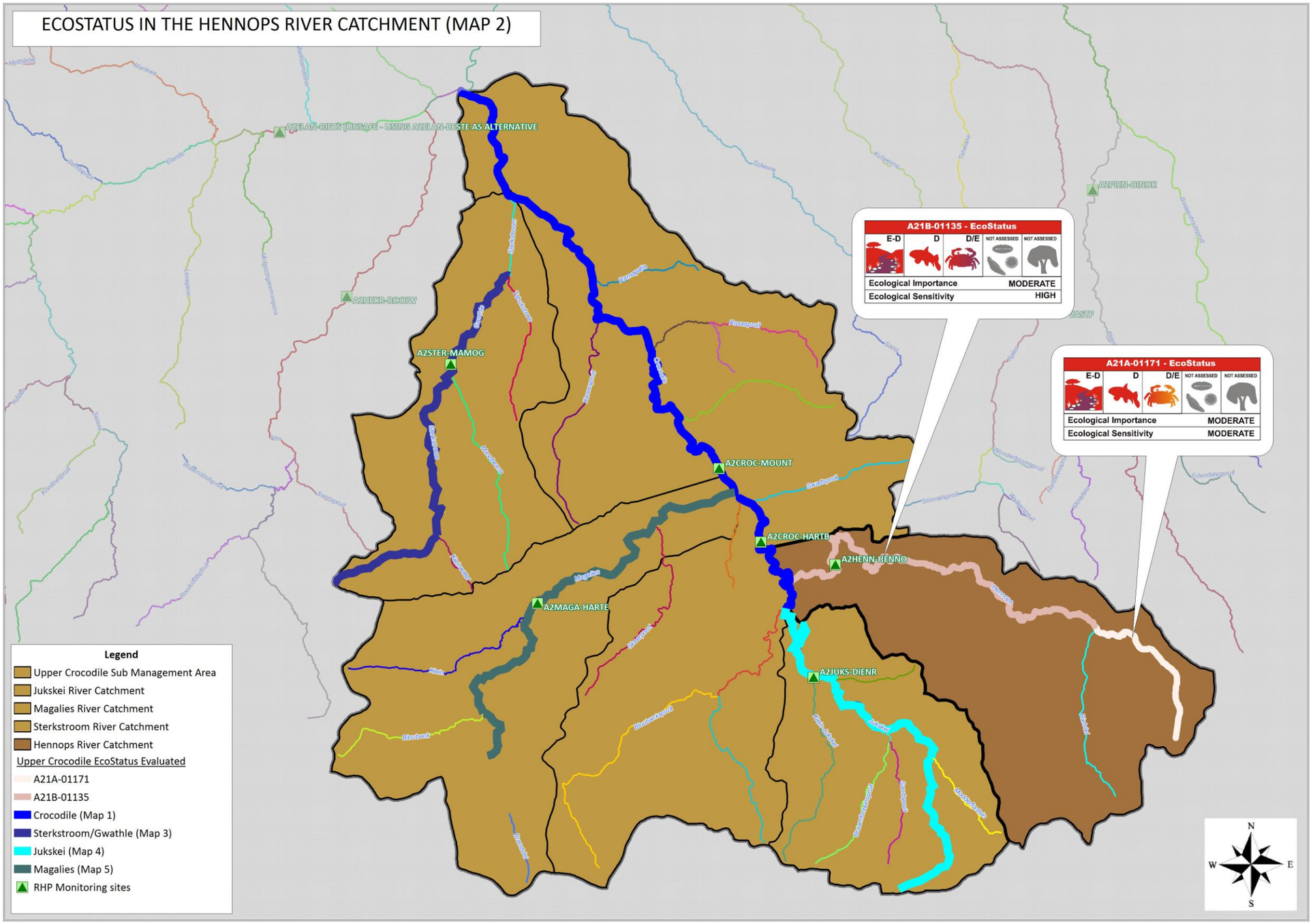


FIGURE 5-10. ECOLOGICAL STATE OF THE HENNOPS RIVER CATCHMENT

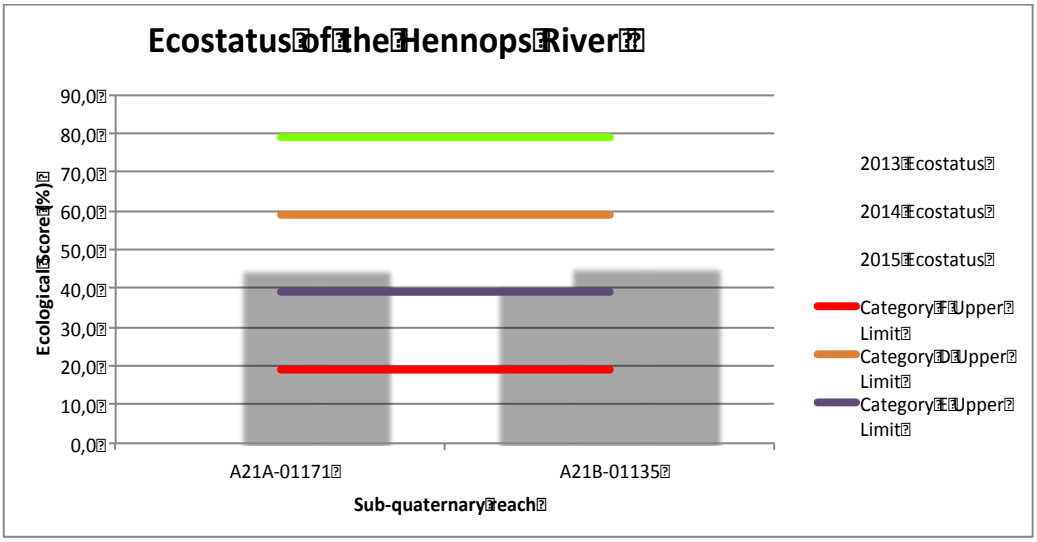


FIGURE 5-11. ECOSTATUS OF THE HENNOPS RIVER FROM UPSTREAM (LEFT) TO DOWNSTREAM (RIGHT)

Visual observations undertaken for the riparian vegetation and fish components Macroinvertebrate data was obtained from external sources and used to determine the EC for this SQR. As can be seen from Figure 5-12 - Figure 5-14, the biota remained stable over the monitoring period, within a mid to low category D.

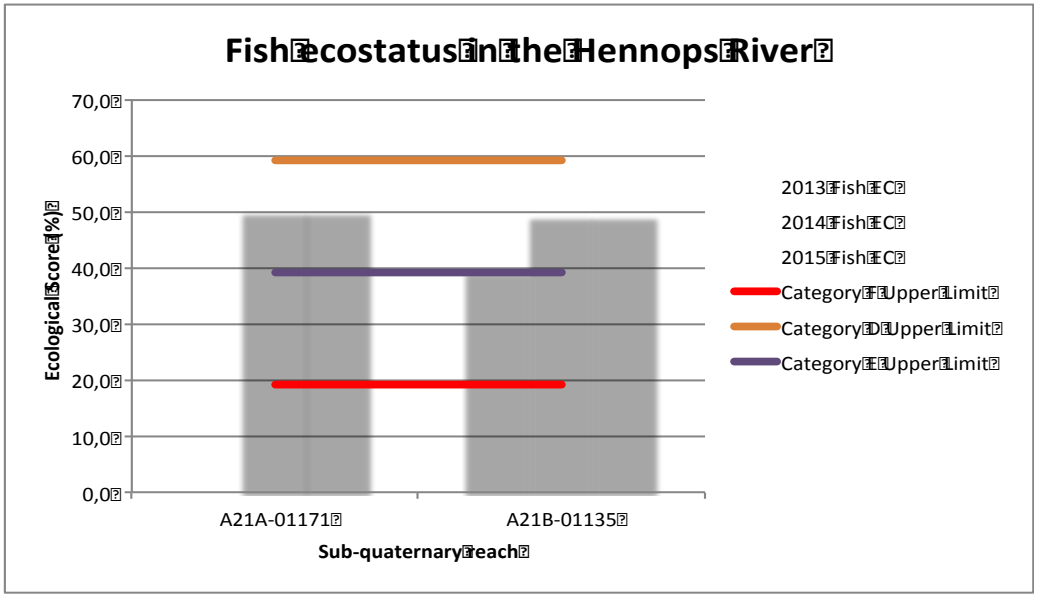


FIGURE 5-12. ECOLOGICAL STATE OF THE FISH IN THE HENNOPS RIVER

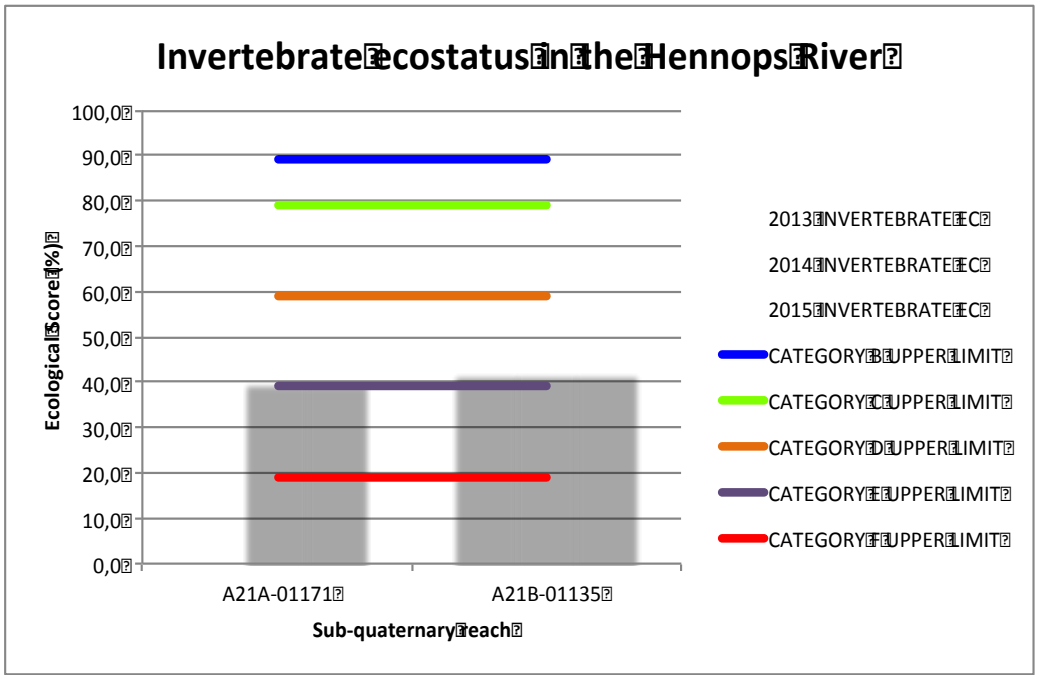


FIGURE 5-13. ECOLOGICAL STATE OF THE MACRO-INVERTEBRATES IN THE HENNOPS RIVER

Observations of riparian vegetation was conducted.

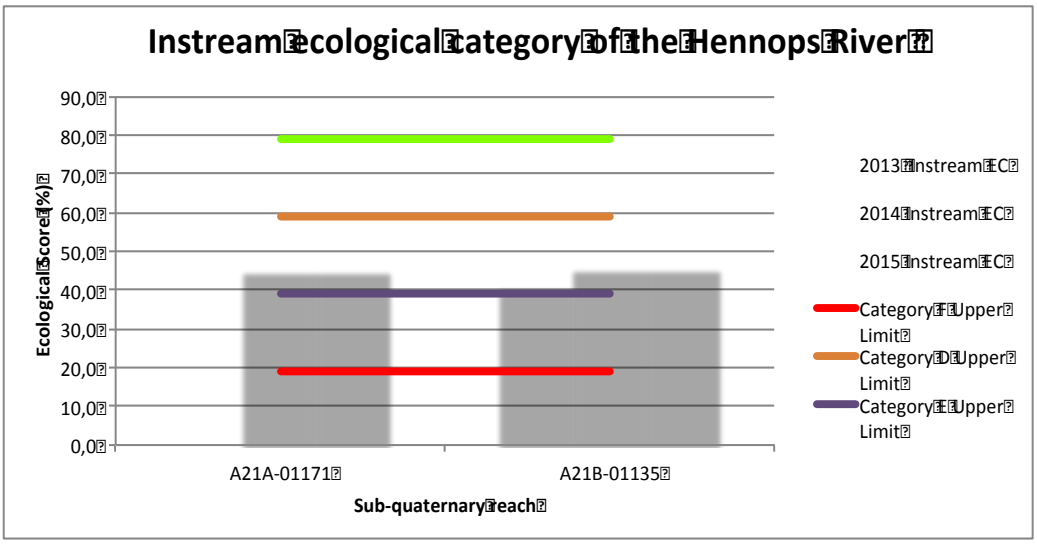


FIGURE 5-14. INSTREAM ECOLOGICAL HEALTH IN THE HENNOPS RIVER

5.3.1 MONITORING RESULTS: REACH A21B-01135 (REPRESENTED BY A2HENN-HENNO)

	
AUGUST 2013	September 2014
	
MARCH 2015	MARCH 2015

FIGURE 5-15. A2HENN-HENNO (A21B-01135)

GENERAL DESCRIPTION

This reach begins in Rietvlei Nature Reserve and includes urbanization impacts from Centurion, industrial impacts, wastewater return flows from the Sunderland Ridge Works, some agriculture, weirs and instream dams.

The lower section of the reach is less impacted than the upper reach section.

FISH

This site was visually surveyed during 2013-2014. The habitat has been assessed to be good and/or adequate to sustain the expected fish species, but the dominant FD habitat at the site will reduce the FROCs of species that prefer SS and SD habitat. All the likely fish species are expected to still be present within this SQ Reach although the Frequency of Occurrence (FROC) of some species has been reduced from reference conditions.

Species with a preference for substrate (rocks and rocky habitat etc.) received reduced FROCs, as there is extensive algae growth present at the site (*Labeobarbus marequensis*, *Labeobarbus polylepis*,

Labeo cylindricus, and *Labeo molybdinus*). Enrichment, from upstream areas, industry, agriculture and mines, will also play a role in the abundance and occurrence of most other species and those intolerant to water quality modification.

Continued flow increases (flow modification) leading to high water levels and higher flows and a change in seasonality will result in habitat loss and species loss. Fast flows also influence territorial species migration and movement negatively.

Enrichment, pollution and high water levels seem to be the major critical impacts at the site and in the area.

The PES and EC have, therefore, been adjusted from 39.5% / D/E during 2013 to 49.2% / D during 2014 (June-Sept 2014).

MACROINVERTEBRATES

Four data sets were used to run the MIRAI to derive an EC of D, with data extending from 2012 to 2013. The water quality metric is the most impacted at 26.7%, followed by the flow modification and habitat metrics.

All taxa with a high and moderate requirement for unmodified physico-chemical conditions are absent. Those taxa with flow preferences for fast, moderate, slow and standing water are largely to critically impacted. Those taxa with a preference for loose cobbles, vegetation, GSM and the water column are also severely impacted. No additional data sets were used to run the MIRAI in 2014 (this site is a tertiary site).

RIPARIAN VEGETATION

Observations at the site was conducted. Good riparian vegetation occurs on the right bank in contrast to the left bank that is disturbed by roads, road-crossing, cultivation, etc. Dominant woody species are *Searsia lancea, Combretum erythrophyllum, Diospyros lycioides*, etc. There is little undergrowth due to leaf litter. The following exotic species occur: *Morus alba, Melia azedarach, Arundo donax, Salix babylonica*, etc. The substrate consists mainly of soil, with some bedrock patches. Erosion has resulted in bank scouring and undercutting, thus limiting the availability of riparian habitat. The root systems of trees are exposed but still provide bank stability.

WATER QUALITY

Diatom samples were not collected at the site. However extensive algal growth present at the site indicates nutrient enrichment.

5.3.2 IMPACTS, THREATS AND MANAGEMENT PRIORITIES IN THE HENNOPS RIVER

The main impacts resulting in the poor ecological condition of the Hennops River include:

- Pollution and nutrient enrichment, due to wastewater discharges, urbanisation (Centurion & Kempton Park), industries, chicken farms and some agriculture.

- Unnaturally high flow conditions, due to wastewater discharges into the river.

Management intervention is necessary to prevent further degradation of the ecological health and sustainability of the river. Management priorities include:

- Implementation of minimum ecological water requirements, including temporal and spatial flow patterns, that have been established by DWS
- Management of the volume and quality of discharges into the system
- Management of non-point source discharge.

5.4 ECOLOGICAL HEALTH OF THE JUKSKEI RIVER

The overall ecological condition of the Jukskei River is in a D category, implying it is highly modified, with a large loss of habitat, biota and ecosystem functioning (Figure 5-16). The site monitored, A21C-01167 (A2JUKS-DIENR), showed a slight improvement in health between 2013 and 2014/15 (Figure 5-17).

Assessment of sub-quaternary reaches was based on a desktop analysis of the Habitat Integrity, using Google Earth imagery. Being a desktop analysis it was not sensitive enough to pick up deterioration in ecological health within the ecological category. The lowest reach of river was sampled, showing that the river is in an upper D ecological category. There seems to be an improvement in ecological health of the reach since 2013, although the condition remains in a D category.

An assessmen of the biota was undertaken at A2JUKS-DIENR. The macro-invertebrates are in a very poor condition, bordering on a D/E category (Figure 5-19). The fish (Figure 5-19) and riparian vegetation (Figure 5-20) are in a slightly better condition, in a D ecological category.

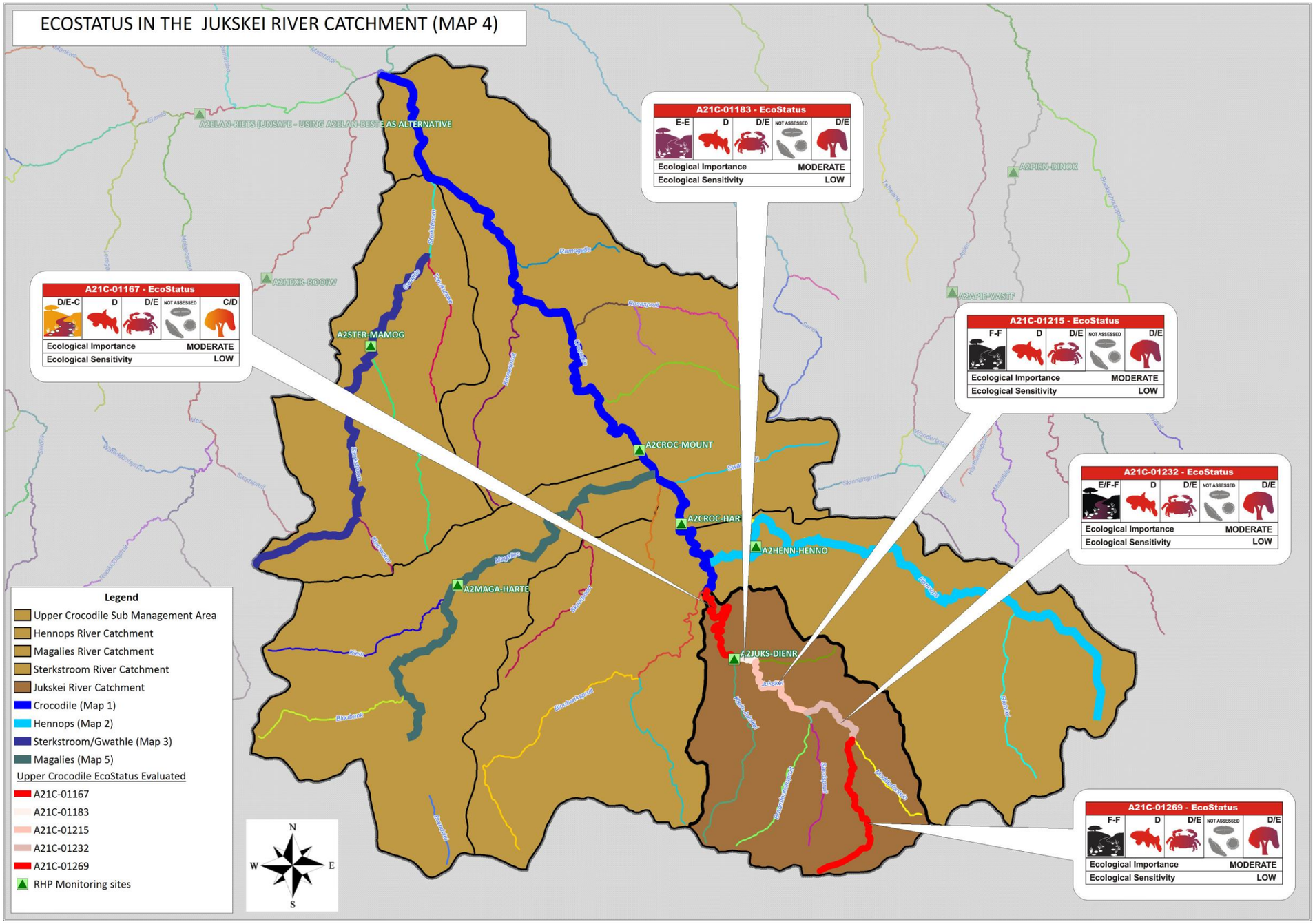


FIGURE 5-16. ECOLOGICAL STATE OF THE JUKSKEI RIVER CATCHMENT

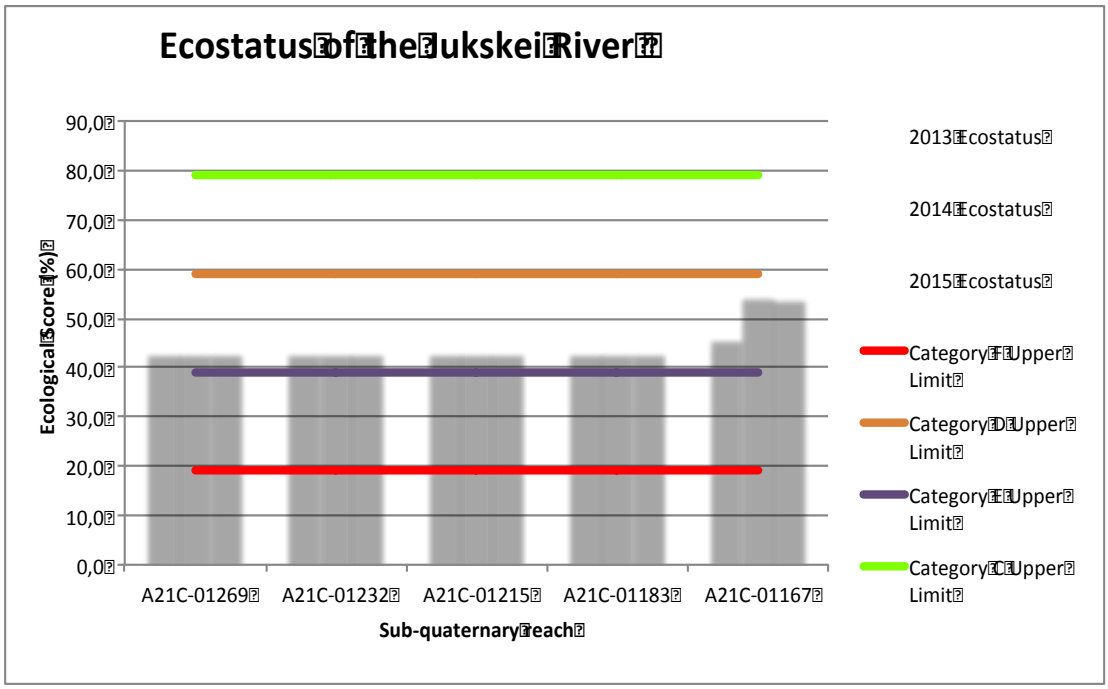


FIGURE 5-17. ECOSTATUS OF THE JUKSKEI RIVER FROM UPSTREAM (LEFT) TO DOWNSTREAM (RIGHT)

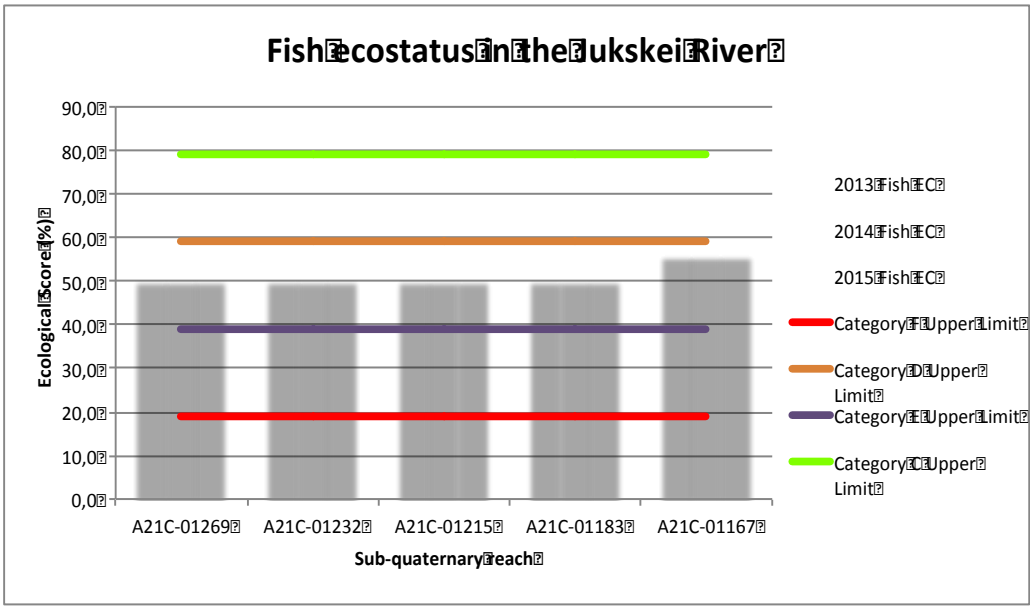


FIGURE 5-18. ECOLOGICAL STATE OF THE FISH IN THE JUKSKEI RIVER

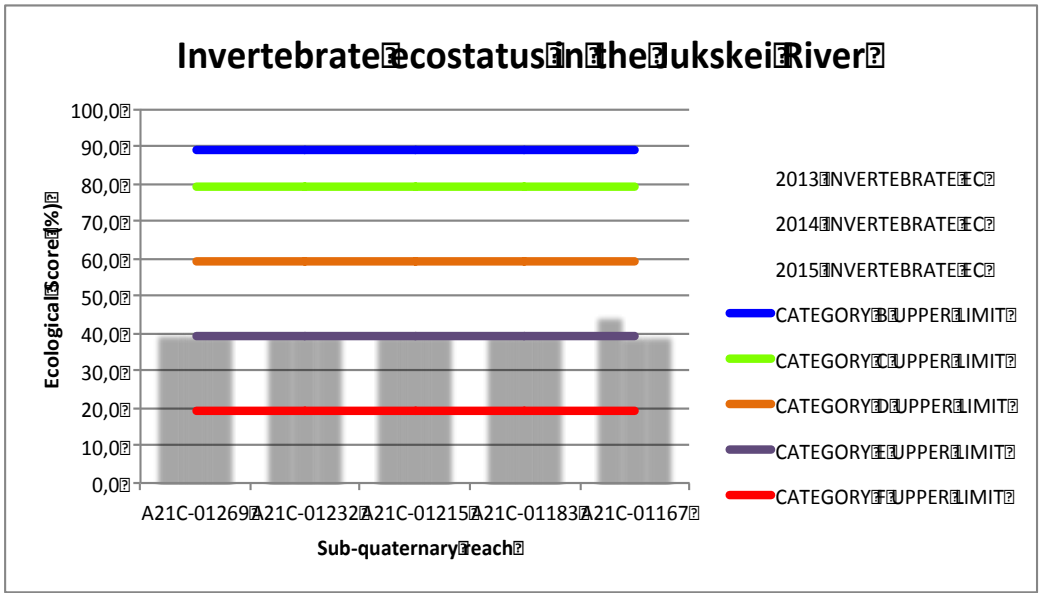


FIGURE 5-19. ECOLOGICAL STATE OF THE MACRO-INVERTEBRATES IN THE JUKSKEI RIVER

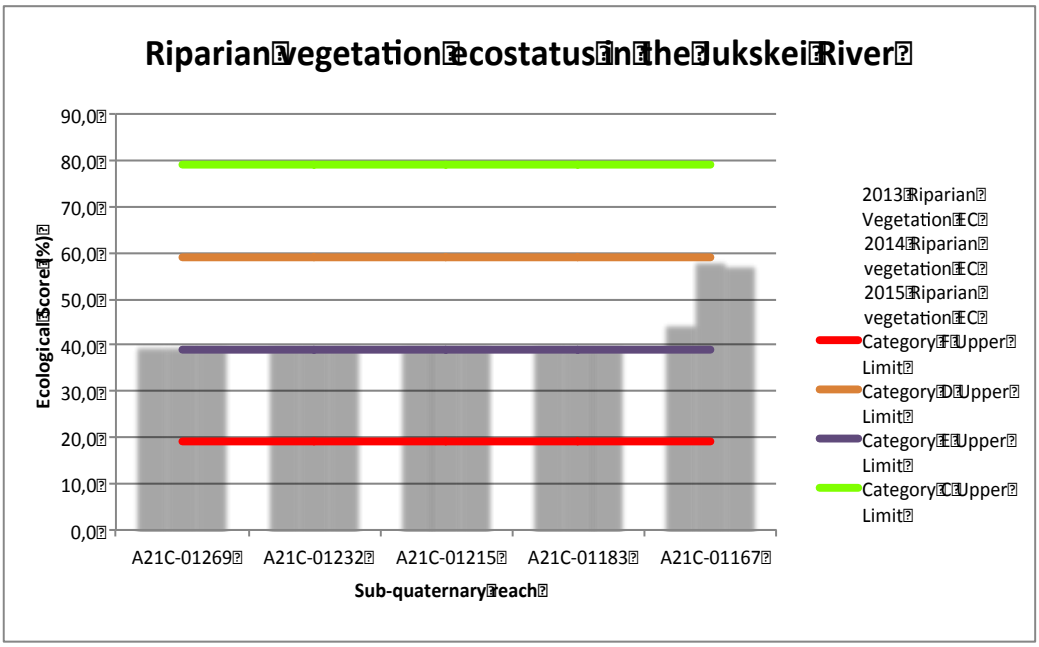


FIGURE 5-20. ECOLOGICAL STATE OF THE RIPARIAN VEGETATION IN THE JUKSKEI RIVER

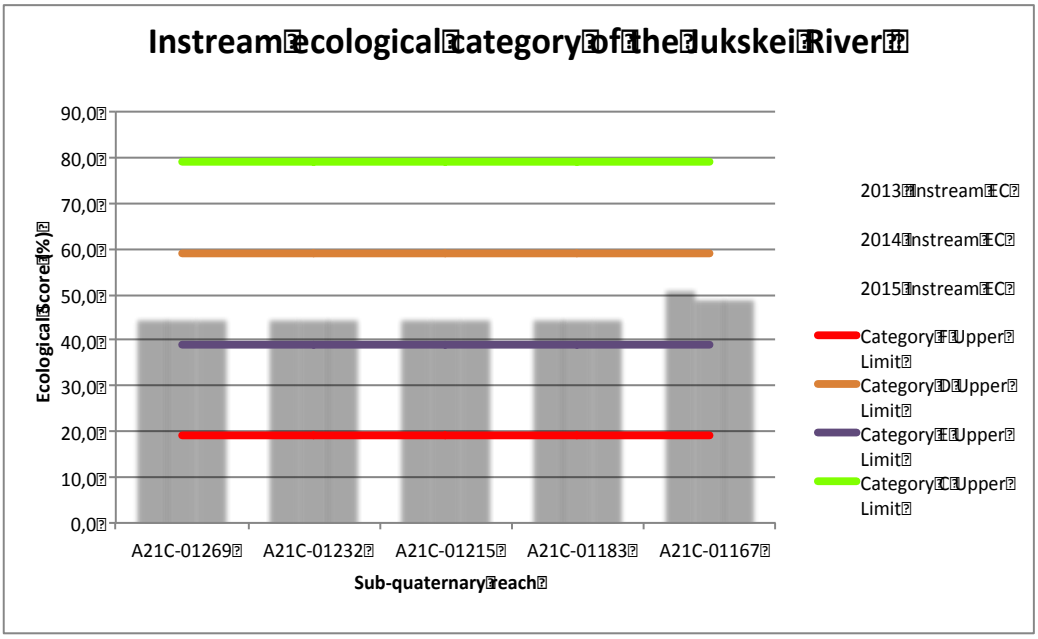


FIGURE 5-21. INSTREAM ECOLOGICAL HEALTH IN THE JUKSKEI RIVER

5.4.1 MONITORING RESULTS: REACH A21C-01167 (REPRESENTATED BY A2JUKS-DIENR)

	
April 2013	September 2014
	
March 2015	March 2015

FIGURE 5-22. A2JUKS-DIENR (A21C-01167)

GENERAL DESCRIPTION

The site is located on the Jukskei River downstream of the Lanseria International Airport, several sand mining operators, many road crossings (including the N14), urban developments and the Diepsloot Township area.

The main impacts coming from the upper catchment, namely impacts from Alexandra, urban impacts, wastewater treatment works, industry, some agricultural small holdings as well as an Interbasin transfer from the Vaal River catchment.

FISH

The site was surveyed during April 2013 and June 2014. During August 2013 and September 2014 the site was visually surveyed due to high flows. The site was visually surveyed during March 2015 due to high flow and sewage input posing a health risk.

The PES and EC remains constant from 2013-2014-2015 (55.9% / D). The EC for A2JUKS-DIENR remains in a D category.

All the expected fish species are expected to still be present within this SQ Reach although the Frequency of Occurrence (FROC) of some species has been reduced slightly from reference conditions due to current impacts.

Species with a preference for substrate (rocks and rocky habitat etc.) received reduced FROC's, as there is siltation/sedimentation and algae growth present at the site. Enrichment is a problem, and this will reduce the FROC's of species that are intolerant and moderately intolerant to WQ modification. Urban run-off and water pollution will also influence the FROC's of species intolerant to water quality modification. Large dams, weirs, and water abstraction (flow modification) leading to low water levels and fewer events for flushing sediments will result in habitat deterioration and species loss. Dams, weirs and low water levels also influence species migration negatively.

Urban run-off is increasing from Gauteng, and therefore the PES will have a negative trend.

MACROINVERTEBRATES

Four data sets were used to run the MIRAI to derive an EC, with data from 2007 to 2014. No sampling was conducted in 2015 due to high flow at the site; hence the EC remains the same as in 2014.

The EC decreased from a D to D/E from 2013 to 2014. Changes to the EC were due to negative impacts in the flow, habitat and water quality metrics.

All taxa with a high requirement for unmodified physico-chemical conditions are absent, whilst those with a moderate requirement for unmodified physic-chemical conditions are mostly absent except for Gerridae and Veliidae which occur at a lower frequency of occurrence than is expected. The presence of taxa with a preference for high, moderate, slow flowing and standing water is highly impacted. The presence of taxa with a preference for loose cobbles, vegetation and GSM are largely impacted.

RIPARIAN VEGETATION

Marginal Zone

This zone is dominated by grass. Vegetation extends into shallow water in places. Clumps of sedges and grass (*Juncus effusus, Cyperus eragrostis, Imperata cylindrica*, *Cynodon dactylon*, *Miscanthus* sp., etc.) occur in and between the bedrock sections. During 2013 extreme sand deposits smothered marginal habitat on the left bank. During the 2014 survey the sandy deposits had been taken away due to flooding. The marginal zone substrate consists of bedrock on the right bank and some sand deposits on the left bank. Many exotic pioneers occur and are dominated by *Arundo donax, Melia azedarach, Verbena officinalis, Tagetes minutes, Ricinus communis*, etc.

Non-marginal Zone

This zone is dominated by trees such as *Combretum erythrophyllum, Gymnosporia buxifolia, Euclea crispa, Diospyros lycioides, Ziziphus mucronata, Ficus ingens*, etc. Bedrock area on right bank provides limited habitat for vegetation. A large portion of the left bank is smothered with deposited sand (alluvial material). High flows do reach some portions of the rocky section. Reasonable cover and abundance of trees occurs on the left bank, with very little cover and abundance of trees on the right bank. Trees such as *Combretum erythrophyllum*, *Cliffortia* sp., *Gymnosporia* sp., *Diospyros lycioides*, etc. are present. Exotic vegetation includes *Arundo donax, Melia azedarach, Gleditsia triacanthos*, *Xanthium strumarium*, etc. Bank substrate consists of bedrock, alluvium (sand) and soil material.

The riparian vegetation is in a C/D category and on a negative trend.

WATER QUALITY

No diatom analysis was conducted for this site.

5.4.2 IMPACTS, THREATS AND MANAGEMENT PRIORITIES IN THE JUKSKEI RIVER

The main impacts resulting in the highly modified ecostatus of the Jukskei River includes:

- Poor water quality due to effluent discharges into the river
- Habitat loss, due to removal of vegetation, sand-mining activities
- Changes in flow regime, due to the transfer of water from the Vaal via the Rand Water Supply system; abstraction and discharges into the system.

Continuing management intervention is required to maintain and/or improve the Jukskei River. Intervention priorities include:

- Control of non-point source discharges into the river
- Management of the quantity and quality of effluent return flows and discharges into the river

- Control of sand-mining activities in the catchment.

5.5 ECOLOGICAL HEALTH OF THE MAGALIES RIVER

The overall ecological health of the Magalies River is moderately to largely modified, placing it in an ecological state of C/D (Figure 5-24). There is a moderate to large loss of natural habitat, biota and ecosystem functioning. Most of the sub-quaternary reaches, A21F-01208; A21F-01168; A21H-01097, were assessed at a desktop level, based on the Habitat Integrity, using Google Earth imagery. This assessment placed the reaches in a lower C ecological category.

Monitoring of site A2MAGA-HARTE, within reach A21F-01116, indicates a decrease in the ecological health of the reach over the 3 years of sampling (Figure 5-24). The reach is currently in a mid D category, with a negative trend.

It is likely that the other reaches are also in a negative trend, however the desktop assessment is not sensitive enough to pick up these changes.

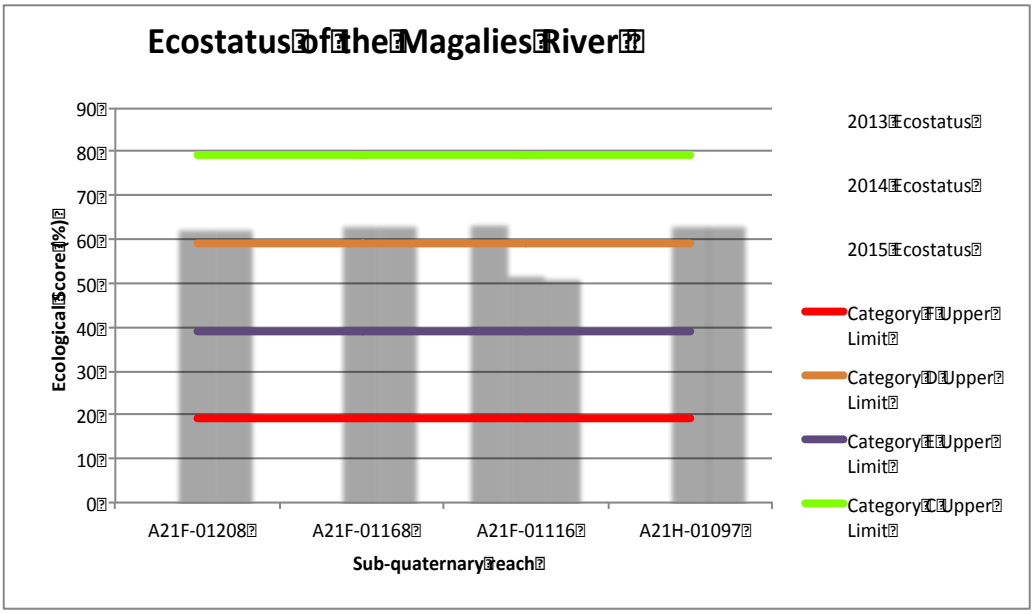


FIGURE 5-23. ECOSTATUS OF THE MAGALIES RIVER FROM UPSTREAM (LEFT) TO DOWNSTREAM (RIGHT)

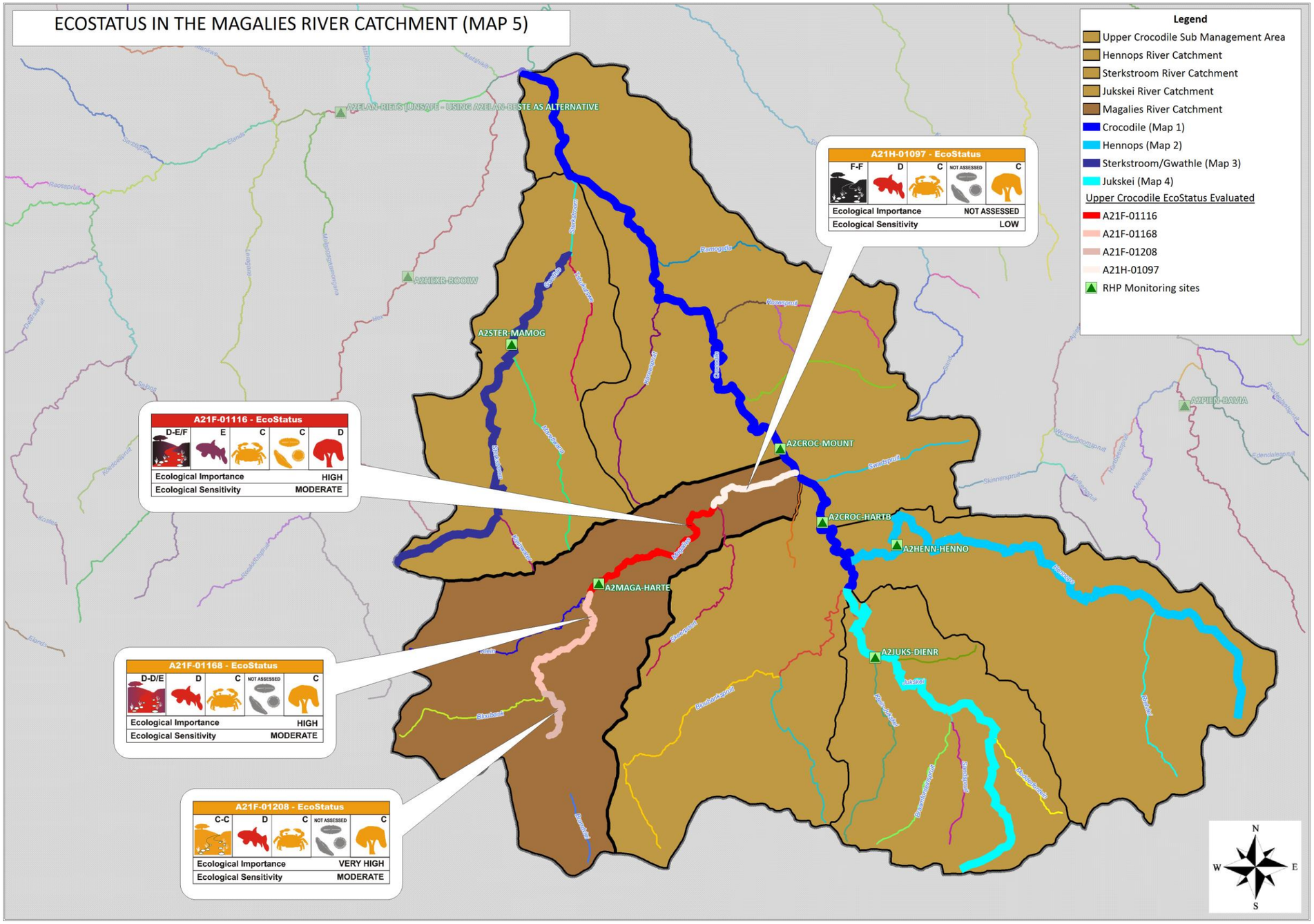


FIGURE 5-24. ECOLOGICAL STATUS OF THE MAGALIES RIVER CATCHMENT

An assessment of the biota was conducted at reach A21F-01116. The results are shown in FIGURE 5-25 - FIGURE 5-28. The fish show a substantial decline in health, dropping to an unsustainable category, E. This is due to habitat loss as a result of algal growth suffocating the system and exotic fish species introduced into the system. The riparian vegetation is also in a poor condition of D, with much alien species, increase in cultivation activities and debris clogging the river. The macro-invertebrates remain in a moderately modified category, C.

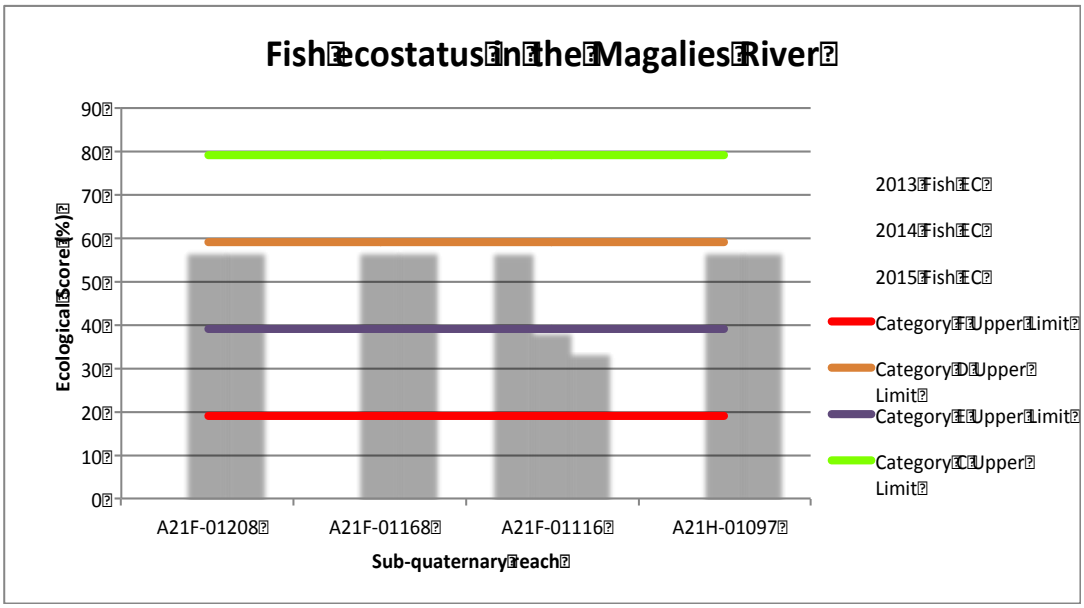


FIGURE 5-25. ECOLOGICAL STATE OF THE FISH IN THE MAGALIES RIVER

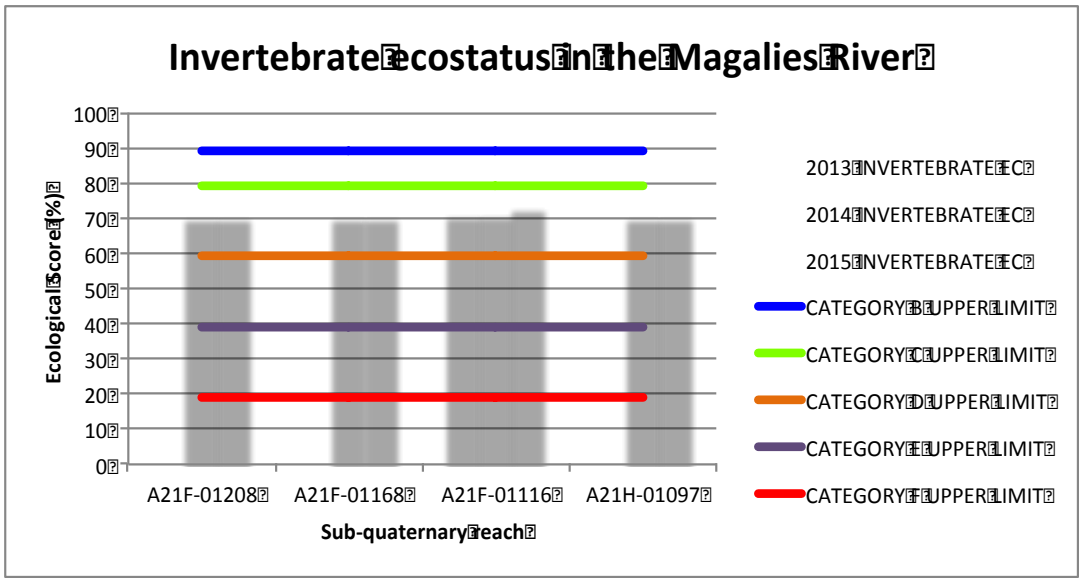


FIGURE 5-26. ECOLOGICAL STATE OF THE MACRO-INVERTEBRATES IN THE MAGALIES RIVER

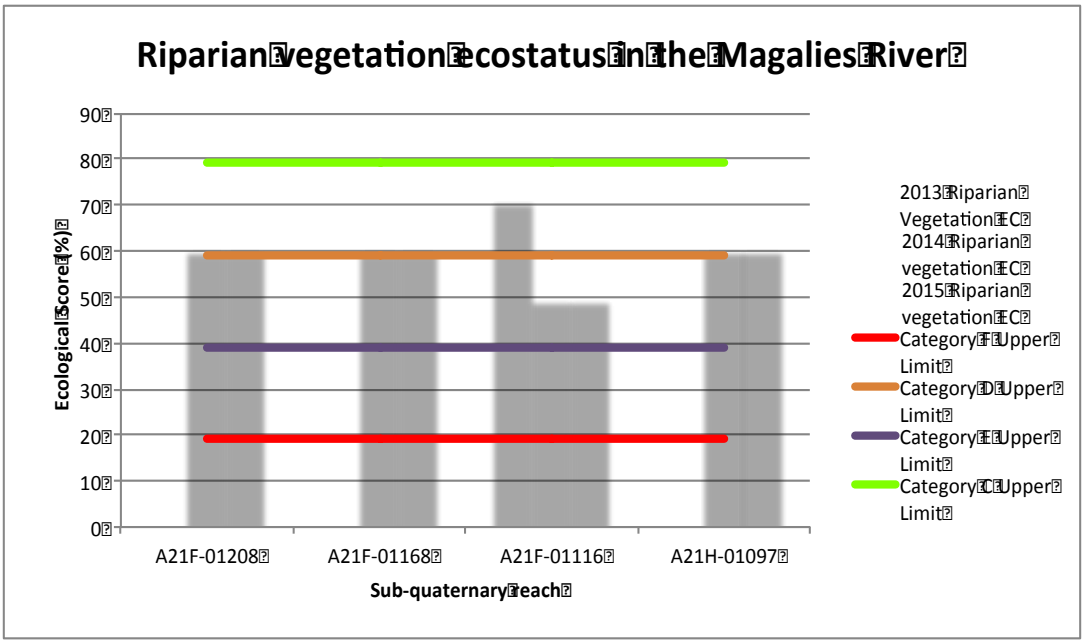


FIGURE 5-27. ECOLOGICAL STATE OF THE RIPARIAN VEGETATION IN THE MAGALIES RIVER

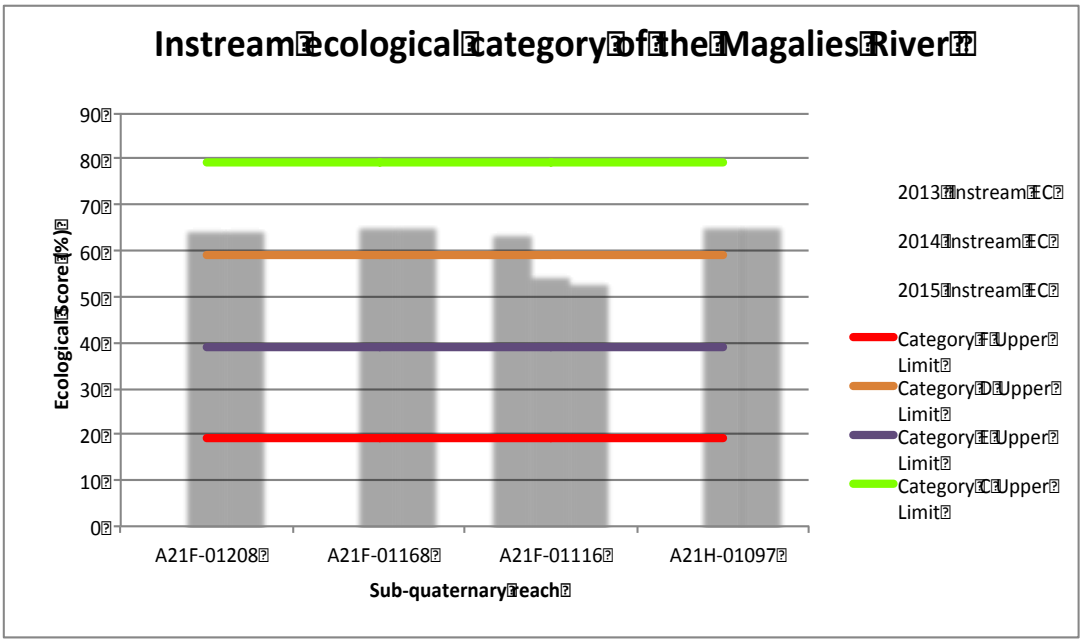


FIGURE 5-28. INSTREAM ECOLOGICAL HEALTH IN THE MAGALIES RIVER

5.5.1 MONITORING RESULTS: REACH A21F-01116 (REPRESENTED BY A2MAGA-HARTE)

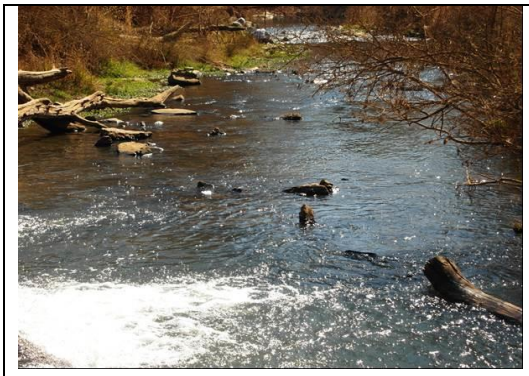
	
August 2013	September 2014
	
March 2015	March 2015

FIGURE 5-29. A2MAGA-HARTE (A21F-01116)

GENERAL DESCRIPTION

This site is situated on the Magalies River, downstream of the R401 road crossing. Dry land and irrigated agriculture are the predominant land use in the catchment. Light industry including pig, chicken and flower farming is also prevalent in the catchment.

FISH

Fish surveys were conducted during August 2013, June and September 2014, and March 2015.

Excessive filamentous algae growth was observed during September 2014 (knee deep in areas) resulting in extreme habitat loss. Less filamentous algal growth was observed during the March 2015 fish survey, but the habitat conditions remain the same as for the previous surveys.

High numbers of BMAR were sampled during March 2015, giving an indication that there is still adequate spawning habitat available for this species (largescale yellowfish). A decrease in the PES/EC

(33.8% E) was, however, derived from the FRAI for March 2015 due to a low water level observed and bass being sampled.

All the expected fish species are expected to still be present within this SQ Reach although the Frequency of Occurrence (FROC) of some species has been reduced slightly from reference conditions. There will be a long term negative trend in the fish species PES due to the presence an alien fish species *Cyprinus carpio* and *Gambusia affinis* , which have a negative impact in native fish species. Species with a preference for substrate (rocks and rocky habitat etc.) received reduced FROC's, as there is siltation/sedimentation and algae growth present at the site. Enrichment may be a problem, and this also influenced the FROC's of species, which are moderately intolerant to WQ modification. Urban and agricultural run-off and water pollution will also influence the FROC's of species intolerant to water quality modification.

Large dams, weirs, and water abstraction (flow modification) leading to low water levels and fewer events for flushing sediments will result in habitat deterioration and species loss. The dams and weirs will also influence species migration.

MACROINVERTEBRATES

Five data sets were used to derive a EC with data from 2012 to 2015. The site remains mostly stable with very minor changes in the macroinvertebrate community detected.

The water quality metric is the most impacted at 66.6%, followed by the flow modification metric and then the habitat metric. Some taxa with a high requirement for unmodified physico-chemical conditions are absent, including >2spp. Hydropsychidae and Perlidae, whilst those with a moderate requirement for unmodified physic-chemical conditions are mostly present, with some for example, Psephenidae, Hydraenidae and Ecnomidae absent. Taxa with a preference for fast flowing water are mostly present, however mostly with reduced frequencies of occurrence. The presence of taxa that show preference for loose cobbles and vegetation is fairly impacted.

RIPARIAN VEGETATION

Marginal Zone

Grass and sedge dominated state. Bare ground also occurs where erosion has taken place. Zone is steep in places and its substrate consists of pebbles and soil. Sedges and grasses in this zone include species such as *Cyperus sexangularis, Juncus punctorius, Plantago longissima, Cyperus sp., Sporobolus africanus*, etc. Hydrophyte species such as *Veronica anagallis-aquatica* and *Nasturtium officinale,* also occur. Exotic vegetation such as *Arundo donax, Verbena officinalis, Tagetes minutes, Melia azedarach, Salix babylonica, Populus x canescens*, etc is present. Indigenous trees such as *Combretum erythrophyllum* and *Celtis africana* occur and are overhanging in places, resulting in a shading effect in the water. Dead tree stumps occur on-site.

Non-marginal Zone

Trees and shrubs dominate. Reasonable to good cover and abundance by trees and shrubs. Trees and shrubs such as *Combretum erythrophyllum*, *Gomphrena fruticosus*, *Gymnosporia buxifolia*, *Diospyros lycioides*, etc. are present. Many forbs occur in places with *Teucrium trifidum* dominating. *Setaria megaphylla* and *Panicum maximum* dominate the grass cover. The upper zone is steep and then

levels out. Many exotic species such as *Arundo donax, Melia azedarach, Gleditsia triacanthos*, etc. infest this zone. Bank substrate consists of soil and pebbles. Moribund material, such as dead tree stumps are present.

The overall vegetation is in a D category with a negative trend.

WATER QUALITY

Site A2 MAGA-HARTE is, according to OMNIDIA, of an ecological category B (Good quality). The site is dominated by species such as *Navicula tripunctata*, *Navicula cryptotenelloides* and *Nitzschia dissipata var. media*, found in eutrophic waters with moderate to high electrolyte content and are good indicators of calcium based salinity. These taxa have been related to fertiliser runoff from agricultural activities as well as urban wastewaters and so an Ecological Category C (Moderate quality) would be a more appropriate classification for the water quality at this site.

5.5.2 IMPACTS, THREATS AND MANAGEMENT PRIORITIES IN THE MAGALIES RIVER

Impacts resulting in the poor ecological health of the Magalies River include:

- Nutrient enrichment, due to urban and agricultural activities, resulting in excessive algal growth.
- Bank scouring due to upstream road bridge, which is resulting in erosion
- Large changes in flow patterns
- Loss of habitat, due to bank scouring, cattle trampling and exotic species
- Introduction of exotic fish and riparian vegetation species.

Management intervention is required to:

- Rehabilitate and restore the bank, which is eroding as a result of the road bridge and cattle trampling.
- Co-operate with environmental organisations for the management of invasive alien species and land-use practices
- Clearing of dead tree stumps from the active channel and riparian zones.

5.6 ECOLOGICAL HEALTH OF THE GWATHLE RIVER

The overall ecological health of the Gwathle/Sterkstroom River is in a largely modified state. There is a large loss of habitat, biota and ecosystem functioning.

The site monitored, A2STER-MAMOG, in the sub-quaternary reach A21K-00959, is within the mining complex before the river enters the Roodekopjes Dam. This site captures impacts from the mining and agricultural activities. From Figure 5-30, it can be seen that the river condition deteriorates as it flows through the Marikana mining area.

Site A2STER-MAMOG, within reach A21K-00959 is in a D ecological category (Figure 5-31).

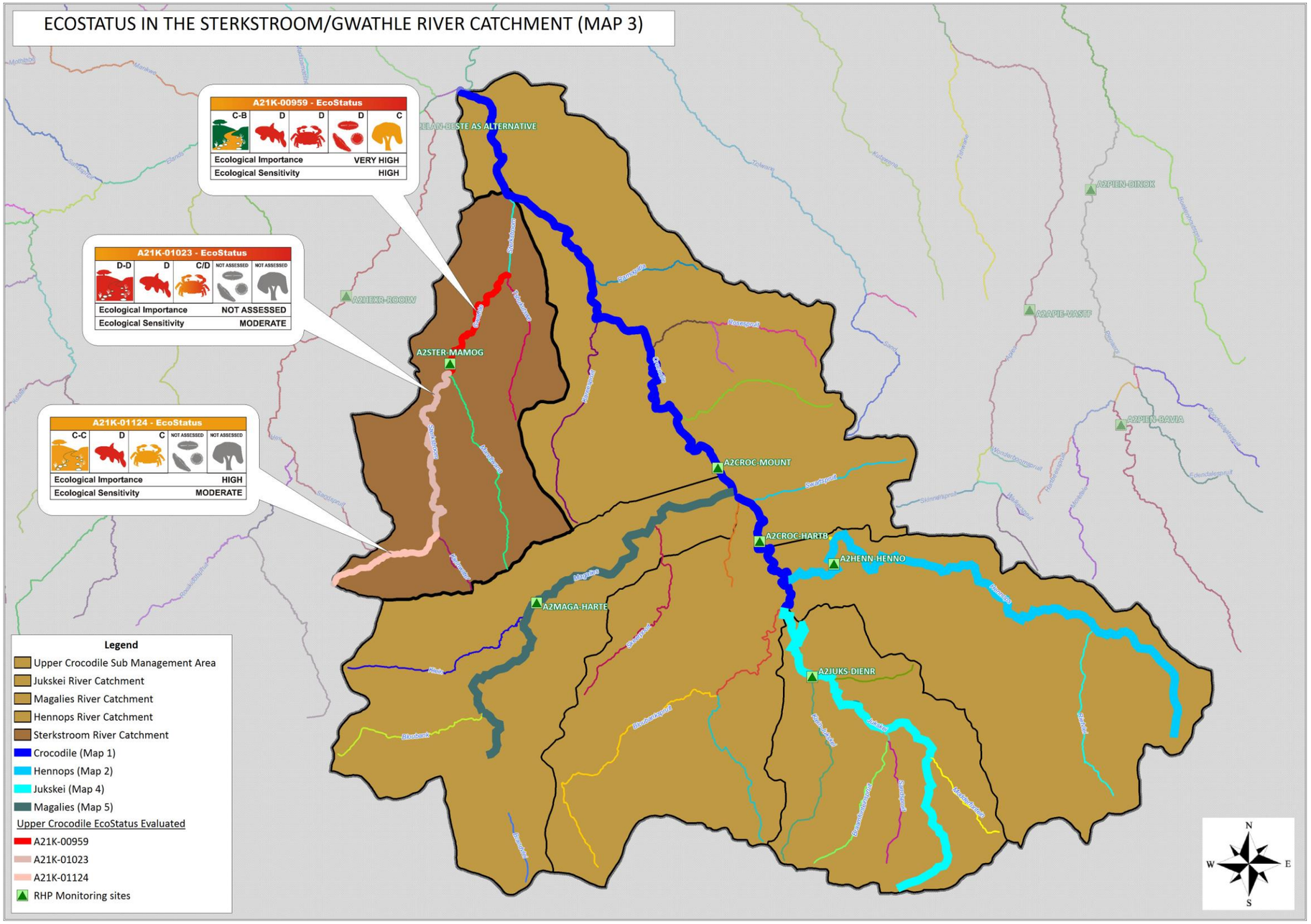


FIGURE 5-30. ECOLOGICAL STATUS OF THE STERKSTROOM (GWATHLE) RIVER CATCHMENT

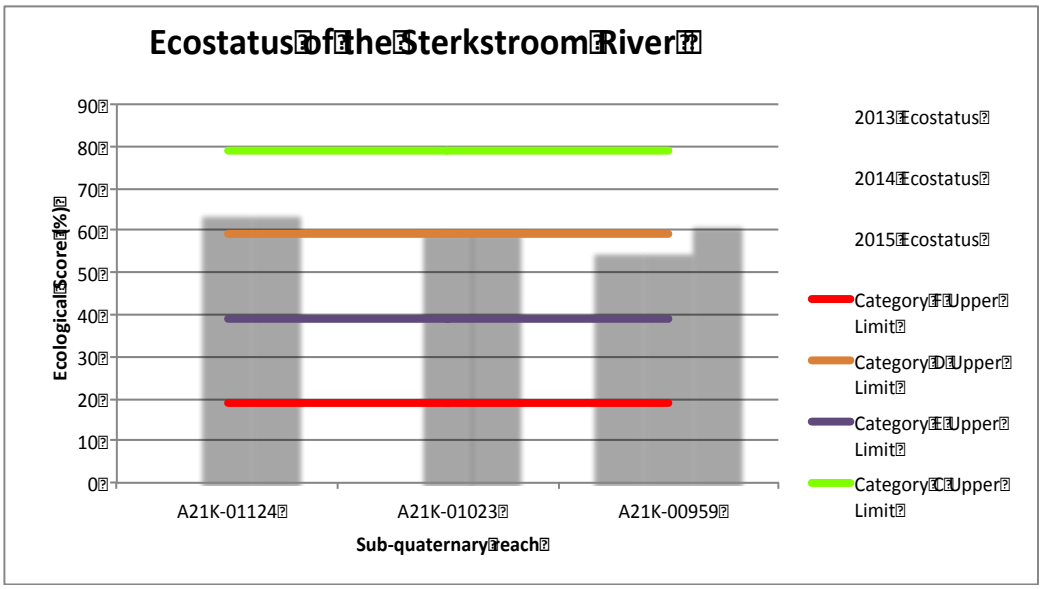


FIGURE 5-31. ECOSTATUS OF THE STERKSTROOM (GWATHLE) RIVER CATCHMENT

An assessment of the biota and instream condition was conducted at site A2STER-MAMOG. The fish showed a slight decline in health in 2015, due to low flow affecting the availability of habitat.

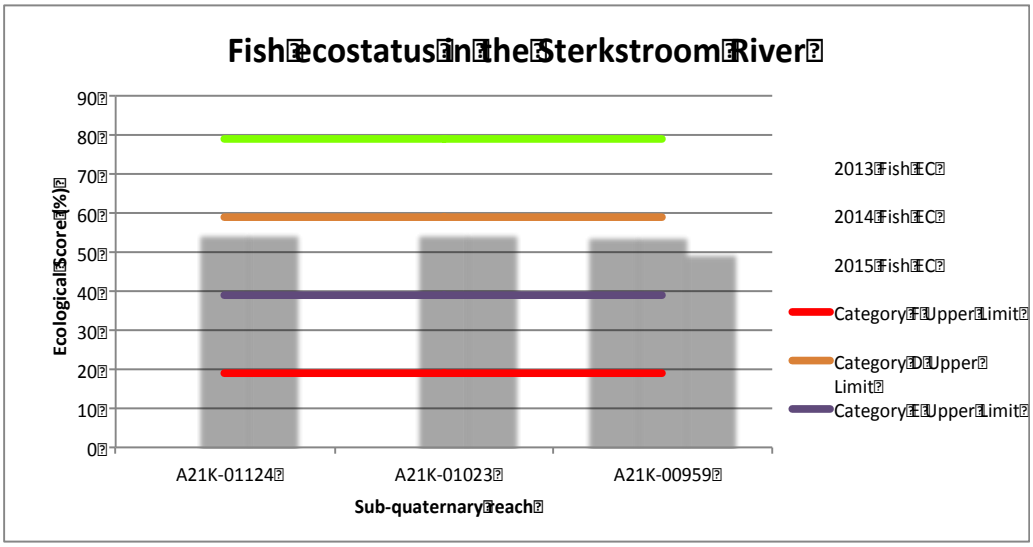


FIGURE 5-32. ECOLOGICAL STATE OF THE FISH IN THE STERKSTROOM (GWATHLE) RIVER

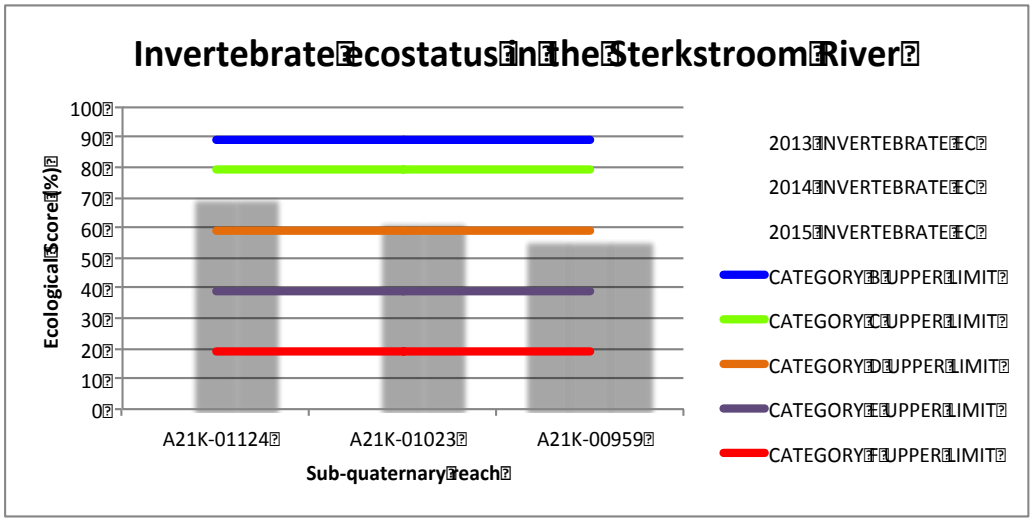


FIGURE 5-33. ECOLOGICAL STATE OF THE MACRO-INVERTEBRATES IN THE STERKSTROOM (GWATHLE) RIVER

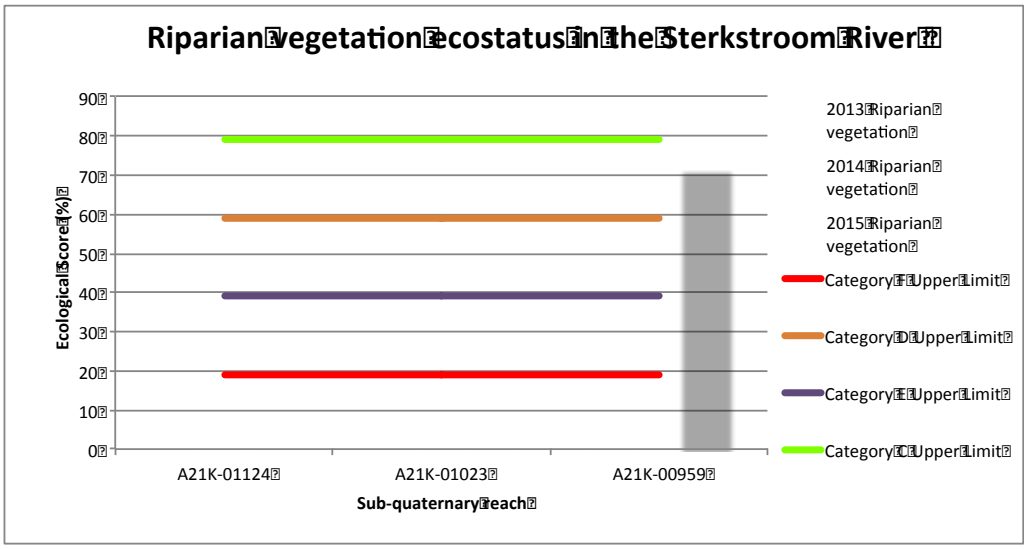


FIGURE 5-34. ECOLOGICAL STATE OF THE RIPARIAN VEGETATION IN THE STERKSTROOM (GWATHLE) RIVER

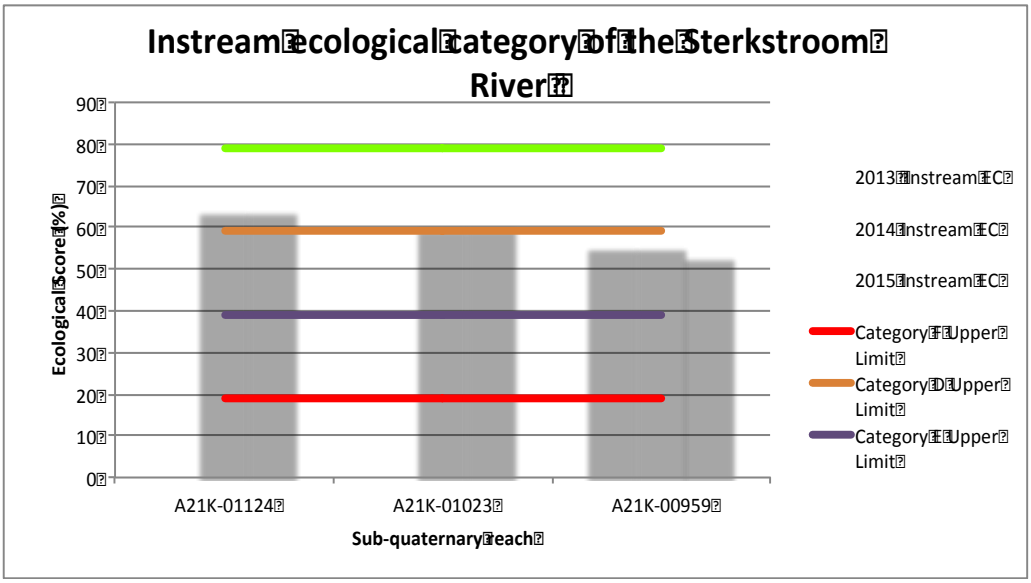


FIGURE 5-35. INSTREAM ECOLOGICAL HEALTH IN THE STERKSTROOM (GWATHLE) RIVER

5.6.1 MONITORING RESULTS: REACH A21K-00959 (REPRESENTED BY A2STER-MAMOG)

	
August 2013	September 2014
	
March 2015	MARCH 2015

FIGURE 5-36. A2STER-MAMOG (A21K-00959)

GENERAL DESCRIPTION

This site is situated on the Sterkstroom, downstream of Marikana and extensive mining and small settlements. A low-flow bridge is situated at the site.

FISH

Fish surveys were conducted during August 2013, September 2014, and March 2015, and the EC and PES was found to fluctuate between a 54.4% D for 2013-2014 to a 49.9% D PES EC category for March 2015. Very low flow recorded/observed during March 2015 has had a negative effect on the fish species FROCs, especially for species with an affinity for fast flowing water/habitat.

Abundant algae growth due to enrichment is a serious problem for this site and the PES and EC will have a negative trend if this problem is not addressed. Mining activities in the area will also have a negative impact on the site and the reach. The electrical conductivity was recorded as very high at the site (highest for the region).

All the expected fish species are expected to still be present within this SQ Reach although the Frequency of Occurrence (FROC) of some species has been reduced from reference conditions.

Species with a preference for substrate (rocks and rocky habitat etc.) received reduced FROC's, as there is siltation/sedimentation and algae growth present at the site (*Labeobarbus marequensis* and *Amphilius uranoscopus*). Enrichment is a problem, and this also influenced the FROC's of species which are intolerant to moderately intolerant to WQ modification (*Amphilius uranoscopus* and *Barbus motebensis*).

Water enrichment, pollution from upstream areas and mines will also influence the FROC's of species intolerant to water quality modification.

Flow modification, in this case low flows, caused by dams and water abstraction, results in poor habitat quality, poor water quality, loss of habitat integrity, and possible loss of species. Cattle activities and enrichment are major critical impacts at the site and in the area. Weirs and dams affect species migration negatively.

MACROINVERTEBRATES

Five data sets were used to run the MIRAI to derive an EC of D from 2006 to 2014. The MIRAI remained stable at 56.0%. No sampling was conducted in March 2015 due to low flow at the site, thus the EC remained the same as in 2014.

The water quality metric is the most impacted at 42.4%, followed by the habitat and then the flow modification metric. Taxa with a high requirement for unmodified physico-chemical conditions are absent, except for >2pp. Baetidae, which occurs at a higher than expected abundance overall, but at a lower frequency of occurrence than expected under natural conditions.

Taxa that have a moderate requirement for unmodified physico-chemical conditions that are also absent in the reach include Elmidae, Tricorythidae, Aeshnidae, Psephenidae and Philopotamidae. The presence of taxa that show preference for loose cobbles is highly impacted.

RIPARIAN VEGETATION

Marginal Zone

Reed and sedge dominated state. Vegetation extends into shallow water in places, resulting in typical wetland habitat (especially upstream of road crossing). Dominant species is *Phragmites australis*, *Cyperus rotundus, Cyperus sexangularis and Persicaria lapathifolia*. Other species consist of *Schoenoplectus brachyceras, Cyperus fastigiatus, Cyperus longus, Juncus effusus, Imperata cylindrica, Senecio latifolius,* etc. Clumps of grass, reeds and sedges are scattered throughout the system where habitat is available. Miscanthus junceus occurs downstream of bridge in clumps. *Salix mucronata* is a woody species that is common in this zone. Substrate consists of bedrock and wetland soils. Some exotic pioneers occur such as *Nasturtium officinale*, *Verbena bonariensis, Tagetes minutes, Ricinus communis,* etc.

Non-marginal Zone

Grass dominated state with trees. A wide terrace occurs downstream of the road crossing with a narrow riparian area on the right bank upstream of the bridge. The following woody species such as *Acacia ataxacantha*, *Ziziphus mucronata, Combretum erythrophyllum, Diospyros lycioides*, *Seersia pyroides*, etc. *Searsia lancea* is the most dominant. Dominant grasses are *Sporobolus africanum, Themeda triandra, Ischaemum afrum, Bothriochloa radicans* and *Polypogon monspeliensis*. Exotic vegetation is present, such as *Sesbania punicea*, *Verbena bonariensis*, *Zinnia peruviana*, *Galium spurium*, etc. Bank substrate consists of rocky material and soil. Low vegetation roughness coefficient due to overgrazing and trampling.

The overall vegetation is in a stable C category.

WATER QUALITY

Recorded at the site is the dominant taxon *Cocconeis pediculus* which favours alkaline, eutrophic waters with elevated electrolyte content, including brackish conditions and is tolerant of moderate organic pollution. Other dominant taxa present are Diatoma vulgaris and Cocconeis placentula *var. placentula* which, combined with *C. pediculus*, points to impacts from agricultural activities, mainly organic and inorganic nutrients, and electrolyte enrichment from fertiliser runoff. South African studies have linked *D. vulgaris* specifically to freshwaters with elevated levels of phosphate-phosphorus. This diatom species is routinely found in high abundances below Bloemhof Dam, which occurs in an irrigated agricultural region. For reasons mentioned above, the biological water quality at these sites should be lowered from the OMNIDIA assigned category B (good quality) to a more suitable category D (Poor quality).

5.6.2 IMPACTS, THREATS AND MANAGEMENT PRIORITIES IN THE GWATHLE RIVER

The main impacts resulting in the loss of ecological health include:

- Increased sedimentation and decreased water quality due to mining and agricultural activities
- Nutrient enrichment, due to agricultural and livestock farming activities

- Loss of species richness/abundance
- Flow modification, due to weirs and abstraction.

Management intervention is required to prevent further degradation of the resource. These include:

- Land-use management
- Management of non-point source discharges
- Management and control of flow impedences
- Implementation of minimum ecological water requirements, as set by the DWS.

6 RESULTS IN THE ELANDS SUB-AREA

The Elands sub-management area consists of the Elands River catchment, which includes the tributaries of the Koster, Selons and Hex rivers (Figure 6-1). The Elands River is a tributary of the Crocodile River and the confluence is situated below Roodekopjes Dam. Large portions of this catchment are tribal areas. Rustenburg is the only major city in this sub-catchment and the major dams are Bospoort Dam on the Hex River and Vaalkop Dam on the Elands River. Mining of platinum and its associated platina group of minerals are the dominant land-use in the catchment and is rapidly expanding.

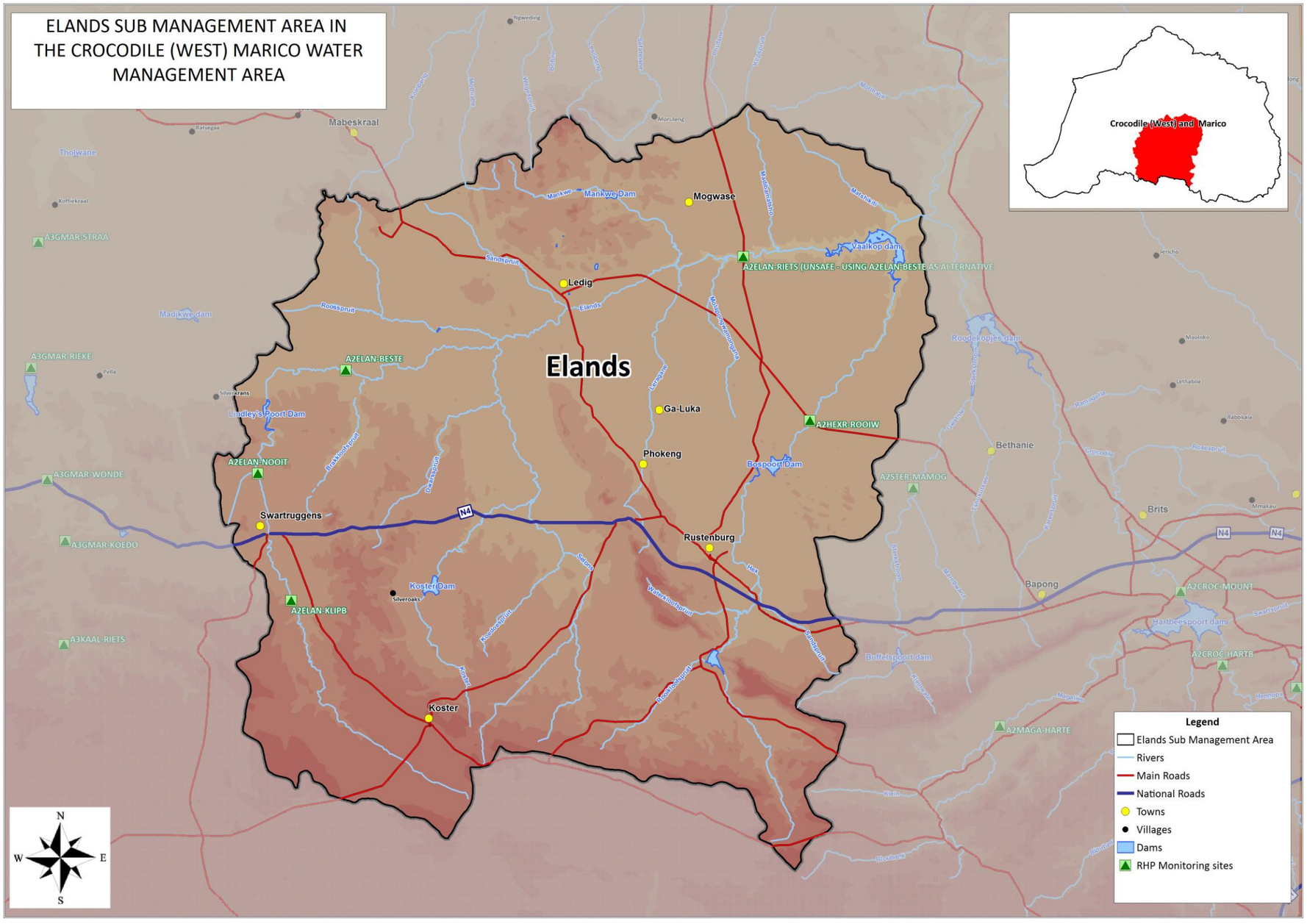


FIGURE 6-1. OVERVIEW OF THE ELANDS SUB-MANAGEMENT AREA

6.1 RIVER HEALTH MONITORING SITES IN THE ELANDS SUB-AREA

Three monitoring sites were selected in the Elands River sub-area. A2ELAN-RIETS was found to be an unsafe site to work at; and was replaced with site A2ELAN-BESTE. A2ELAN-KLIPB site had become inaccessible in April and August 2013 due to mine closure. A2ELAN-NOOIT was monitored in this reach. These sites are representative of the reaches in which they are located. Table 6-1 provides the sub-quaternary reaches within the Elands Sub-Area and the River Health Monitoring Sites that have been sampled over the project period.

TABLE 6-1. SUB-QUATERNARY REACHES AND RIVER HEALTH MONITORING SITES IN THE ELANDS SUB-AREA

MONITORING SITE	SQ REACH	RIVER NAME	SQR NUMBER	LATITUDE	LONGITUDE
A2ELAN-KLIPB A2ELAN-NOOIT	A22A-01001	Elands	E01.00	-25.72656 -25.58181	26.72044 26.67822
	A22E-00940A	Elands	E02A.00		
A2ELAN-BESTE	A22E-00940B	Elands	E02B.00	-25.46392	26.78925
	A22E-00931	Elands	E03.00		
	A22F-00939	Elands	E04.00		
	A22F-00918	Elands	E05.00		
	A22F-00869	Elands	E06.00		
	A22F-00895	Elands	E07.00		
	A22F-00791	Elands	E08.00		
A2ELAN-RIETS (UNSAFE USING A2ELAN-BESTE AS ALTERNATIVE	A22F-00845	Elands	E09.00	-25.33489	27.29089
	A22F-00818	Elands	E10.00		
	A22J-00865	Elands	E11.00		
	A22J-00831	Elands	E12.00		
	A22G-01131	Hex	HX01.00		
	A22H-01094	Hex	HX02.00		
	A22H-01076	Hex	HX03.00		
	A22J-00878A	Hex	HX04A.00		
A2HEXR-ROOIW	A22J-00878B	Hex	HX04B.00	-25.52136	27.37528

6.2 ECOLOGICAL HEALTH OF THE ELANDS RIVER

The ecological health of the Elands River deteriorates as it passes Sun City and flows through the lower catchment. The Upper catchment is in a low C category and the lower catchment in a middle D category (FIGURE 6-2). The health has remained fairly stable over the 3 years of monitoring (Figure 6-3).

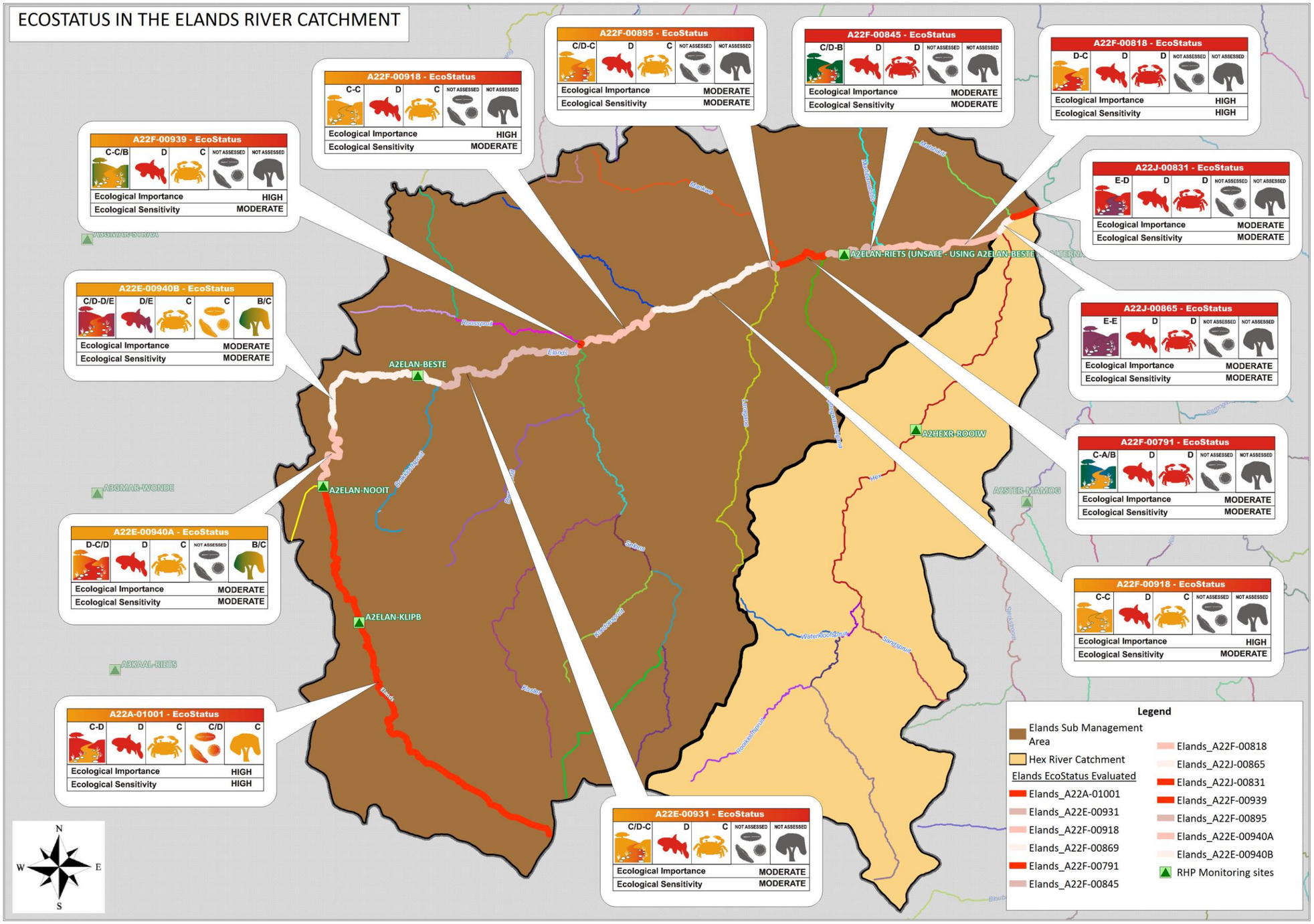


FIGURE 6-2. ECOLOGICAL STATUS OF THE ELANDS RIVER CATCHMENT

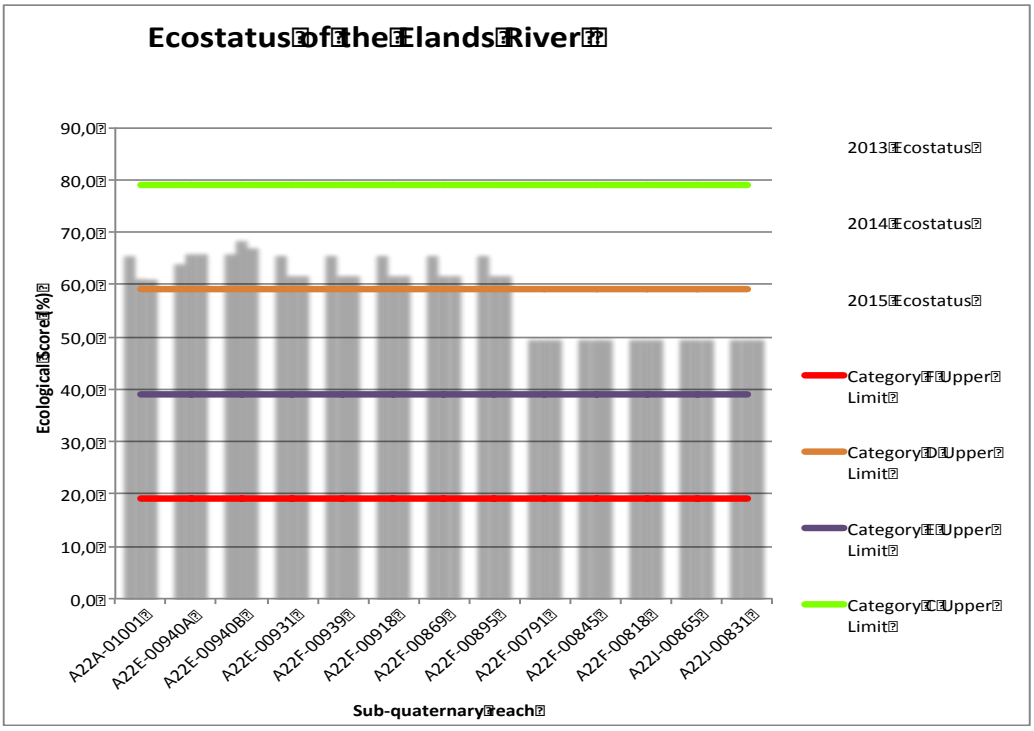


FIGURE 6-3. ECOSTATUS OF THE ELANDS RIVER FROM UPSTREAM (LEFT) TO DOWNSTREAM (RIGHT)

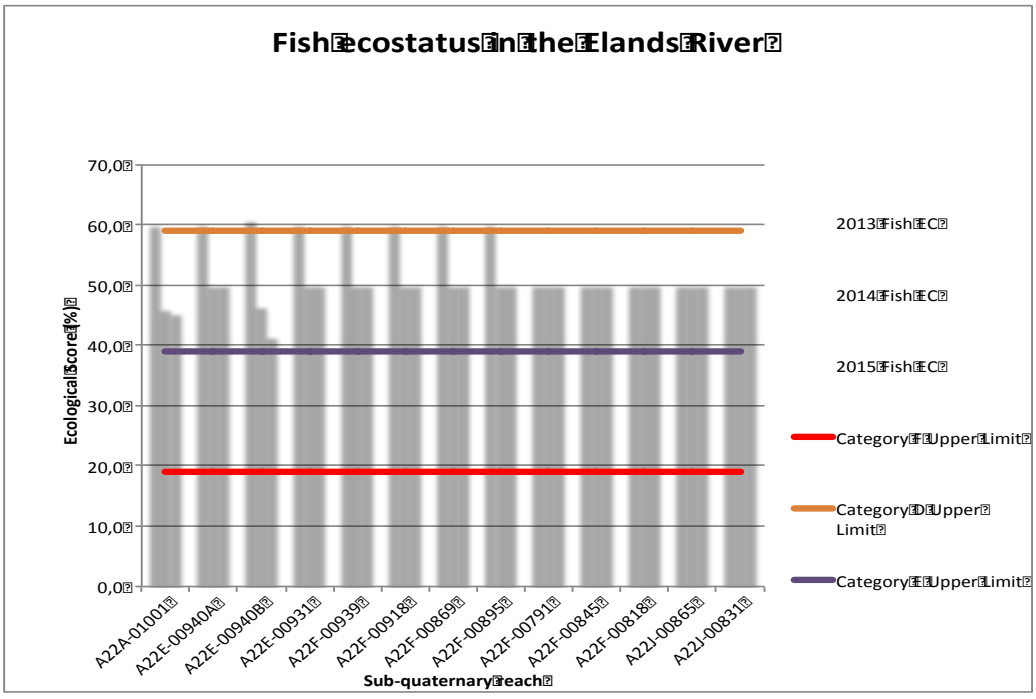


FIGURE 6-4. ECOLOGICAL STATE OF THE FISH IN THE ELANDS RIVER

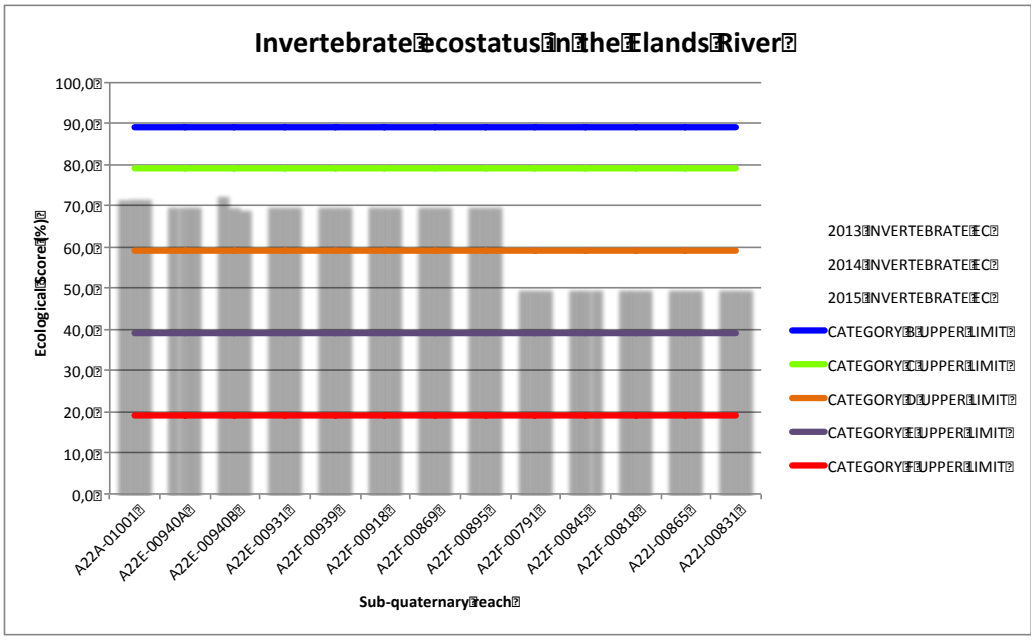


FIGURE 6-5. ECOLOGICAL STATE OF THE MACRO-INVERTEBRATES IN THE ELANDS RIVER

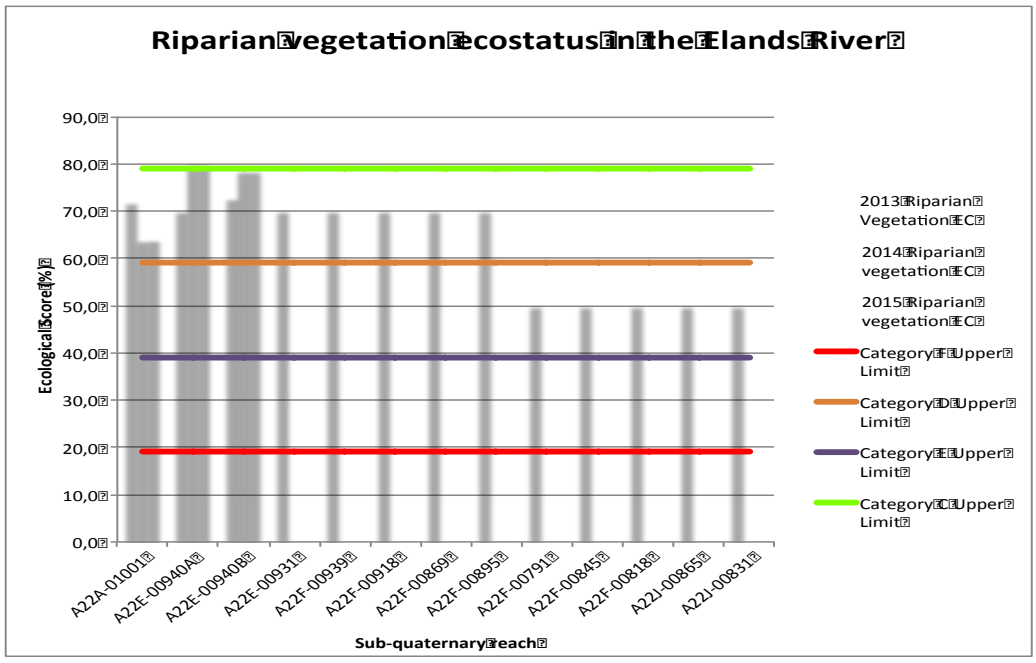


FIGURE 6-6. ECOLOGICAL STATE OF THE RIPARIAN VEGETATION IN THE ELANDS RIVER

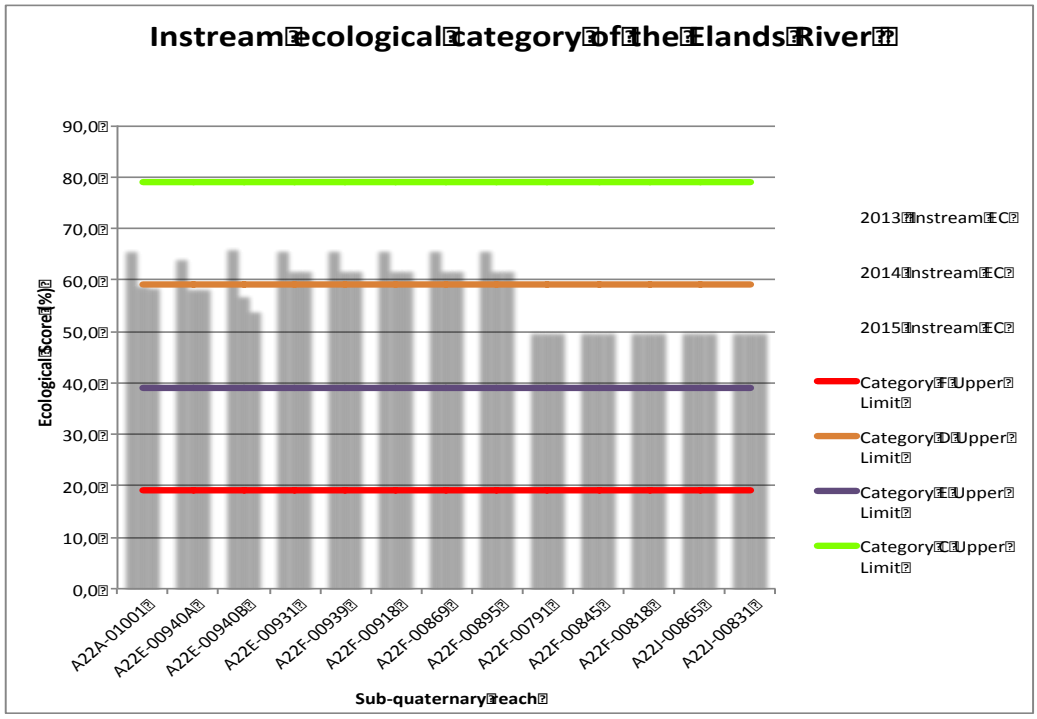


FIGURE 6-7. INSTREAM ECOLOGICAL HEALTH IN THE ELANDS RIVER

6.2.1 MONITORING RESULTS: REACH A22A-01001 (REPRESENTED BY A2ELAN-KLIPB AND A2ELAN-NOOIT)

	
August 2013	September 2014
	Insert a photo here
March 2015	

FIGURE 6-8. A2ELAN-KLIPB (A22A-01001)

	
June 2014	September 2014 (After a sewage spill)
	Insert a photo here
March 2015	

FIGURE 6-9. A2ELAN-NOOIT (A22A-01001)

GENERAL DESCRIPTION

This site is situated on the Elands River, upstream of the town of Swartruggens, adjacent to a slate mine. Dry land farming is the dominant land use in this reach, with Swartruggens, a settlement and a wastewater treatment works in the lower section of this reach. A small settlement is present in close proximity to the Elands River at this site. No sampling was conducted during April or August 2013 due to mine closure and access not allowed onto the premises.

A2ELAN –NOOIT is situated in the same SQR as A2ELAN-KLIPB, but immediately downstream of a low-flow bridge, downstream of Swartruggens.

FISH

A2ELAN-NOOIT

Fish sampling was conducted during April 2013 and June 2014. During the other surveys it was visually surveyed due to no flow, very high flow, or as in 2015, due to sewage spills posing a health risk.

The PES and EC have reduced/deteriorated from 2013 (C/D) to 2014 (D) due to severe impacts from sewage spills in the reach. Site conditions remained the same for the March 2015 survey, but after specialist/expert

inputs, considerations and discussions the EC of this site may/could be further reduced, as the EC of this site has a definite negative trend.

Low flows also negatively affected the FROCs of species with a high affinity for FS and FD habitat.

A2ELAN-KLIPB

This site was surveyed during June and September 2014, and March 2015. The PES and EC has declined from 2014 to March 2015 mainly due to largemouth bass sampled during March 2015. Low flow is prevalent for this site. No major changes in habitat conditions were observed for the site from 2014-2015. Very low flow was, however, present during March 2015, and continuous low flows and cattle trampling will lead to a negative trend for the PES and EC for this site. The PES EC has declined from 2013-2014 (62% C) to 2015 (44.9% D) mainly due to lower flow and the impact from *Micropterus salmoides* (largemouth bass).

MACROINVERTEBRATES

Twenty data sets were used to run the MIRAI from 2006 to 2014. The MIRAI remained stable over the 3 year sampling period, at a C (72.0%). The water quality metric is the most impacted at 62.6%, followed by the flow modification and habitat metric. Taxa with a high requirement for unmodified physico-chemical conditions are mostly present, except for Perlidae, Helodidae and Amphipoda. However, those that do occur generally have a lower frequency of occurrence than expected under natural conditions.

Taxa that have a moderate requirement for unmodified physico-chemical conditions that are also absent in the reach include Tricorythidae, Hydraenidae and Polymitarcyidae. The presence, abundance and frequency of occurrence of taxa that show preference for loose cobbles is moderately impacted. Physidae occur in this reach, which is not expected under natural conditions as these are exotic taxa.

Data was collected in 2015, only for A2ELAN-KLIPB, as very low flow dominated at A2ELAN-NOOIT. Furthermore, sewage was also present at A2ELAN-NOOIT, which is considered a health risk.

RIPARIAN VEGETATION

A2ELAN-NOOIT

The vegetation is in C category, with a stable trend.

Marginal Zone

Trees and grasses/sedges dominate. Vegetation extends into water in places. Clumps of sedges, such as *Cyperus sexangularis, Juncus effusus, Equisetum ramosissimum, Schoenoplectus brachyceras*, *Phragmites australis*, etc. Signs of trampling and grazing can be seen. Many woody species such as *Combretum erythrophyllum, Protasparagus setaceus*, and *Diospyros whyteana* are present. Left bank is scoured with the roots of trees exposed. Overhanging trees create shade over marginal zone. Marginal zone is very steep in places. Substrate consists of rock and soil. Human activities occur in the form of footpaths. Many exotic trees and pioneers are present (*Salix babylonica, Pyracantha angustifolia, Verbena bonariensis, Tagetes minutes, Ricinus communis,* etc.).

Non-marginal Zone

Tree and shrub dominated state. Steep slope that levels out on top of the bank. Both banks have good cover and abundance of trees and shrubs: *Combretum erythrophyllum*, *Searsia pyroides*, *Celtis africana*, *Diospyros lycioides*, *Diospyros whyteana*, etc. The left bank is especially infested with exotic vegetation such as *Morus alba*, *Melia azedarach*, *Salix babylonica*, *Populus alba*, etc. The bank substrate consists of rock and soil material. Cattle tracks are visible, with signs of overgrazing. Constructed cement slab and cables indicate that this area was used as a crossing in the past.

A2ELAN-KLIPB

The vegetation is in C category, with a negative trend.

Marginal Zone

Grass and sedge dominated state. Vegetation extends into shallow water in places, resulting in typical wetland habitat. Dominant species is *Cyperus digitatus*. Other species consist of *Cyperus sexangularis, Schoenoplectus brachyceras, Juncus effusus, Imperata cylindrica, Centella asiatica, Typha capensis* and *Phragmites australis*, etc. Clumps of grass, reeds and sedges are scattered throughout the system where habitat is available. *Salix mucronata* is a woody species that is common in this zone. Substrate consists of bedrock and soil. Some exotic pioneers occur such as *Nasturtium officinale*, *Verbena bonariensis, Tagetes minutes, Ricinus communis,* etc.

Non-marginal Zone

Grass dominated state with trees. A wide terrace occurs on the left bank with a narrow riparian area on the right bank. The wide terrace does have good grass cover and abundance of trees. The following tree species occur: *Searsia lancea, Acacia karroo, Celtis africanus, Olea europaea, Ziziphus mucronata, Combretum erythrophyllum, Diospyros lycioides*, etc. *Searsia lancea* is the most dominant. Dominant grasses are *Sporobolus africanum, Themeda triandra* and *Polypogon monspeliensis*. Exotic vegetation is present, such as *Sesbania punicea*, *Solanum pseudocapsicum, Salix babylonica, Eucalyptus grandis*, etc. Bank substrate consists of rocky material and soil. Low vegetation roughness coefficient due to overgrazing and trampling.

WATER QUALITY

The site is dominated by *Cyclostephanos dubius*, which is tolerant of eutrophication. The slight presence of taxon Cocconeis placentula points to minor nutrient enrichment at the site. The water quality at Site A2 Elan-Klipb can be assigned an ecological category C (Moderate quality).

The ecological water quality at Site A2 ELAN-NOOIT is in a category C (Moderate quality) with a moderate amount of organic content in the system (26 %PTV) as reflected by the presence of dominant taxon *Gomphonema parvulum*.

6.2.2 MONITORING RESULTS: REACH A22A-00940B (REPRESENTED BY A2ELAN-BESTE)

	
August 2013	September 2014 (algal growth)
	Insert a photo here
March 2015	

FIGURE 6-10. A2ELAN-BESTE VISUALS

GENERAL DESCRIPTION

This site is situated on the Elands River, approximately 15 kilometres downstream of Lindleyspoort Dam, in an agricultural area. Dry land as well as irrigated agriculture occurs in this reach. This site replaces A2ELAN-RIETS for safety reasons. It was visited once in August 2013 but could not be sampled due to no flow present. Standing pools were present, with braided sections downstream of the road bridge. A weir is situated immediately upstream of the road bridge.

FISH

A visual survey was conducted during August 2013 and the FRAI applied using specialist opinion, field notes, photos, and a habitat integrity assessment done to determine habitat suitability for the fish expected to occur. Two fish surveys were conducted during June and September 2014, and the PES and EC was found to be similar and constant to that calculated (46.6% D) from a visual survey during August 2013. A fish survey was conducted during March 2015 and EC was reduced to a 41.5% D/E due to low flow conditions and less habitat

available for fish. Low flow conditions affect the FROCs of species with an affinity for fast flowing habitat. There is a negative trend in the ecological status of the fish in this reach.

MACROINVERTEBRATES

Seven data sets were used to run the MIRAI to derive an EC of C, with a fairly stable trend. Changes to the system are mainly those relating to decreased water quality. The most impaired metric is that of water quality, followed by flow modification and instream habitat modification. Taxa that have a high requirement for unmodified physico-chemical conditions and that are absent in the reach include Perlidae, Heptageniidae and >2spp. Hydropsychidae, whilst those that are absent with a moderate requirement for unmodified physic-chemical conditions include Elmidae, Psephenidae and Tricorythidae. >2spp Baetidae show a decreased frequency of occurrence during the period assessed. Taxa with a preference for fast flowing water, i.e. >0.6m/s are largely impacted. Overall, the water quality driver seems to be contributing the most to the impairment of the river in this reach, as is reflected in the absence of taxa with a high and moderate requirement for unmodified physico-chemical conditions.

RIPARIAN VEGETATION

The vegetation is in B/C category, with a negative trend.

Marginal Zone

Grass and reed dominated state. Vegetation extends into shallow water in places and also in and around sandy bars. Species in the area include *Juncus dregeanus, Cyperus sexangularis, Cyperus marginatus, Pycreus pelophilus, Kyllinga alata, Phragmites australis*, *Gomphostigma virgatum*, etc. Deep scouring (bank collapse) is taking place, with bank scouring also occurring in places. Clumps of grasses such as *Paspalum distichum*, reeds and sedges are scattered throughout the system where habitat is available among all the rocks. Substrate consists of bedrock, boulders, loose rocks and soil. Some exotic pioneers occur (*Verbena bonariensis, Tagetes minutes, Ricinus communis,* etc.).

Non-marginal Zone

Tree and grass dominated state. Steep slopes are present in places due to bank collapse. Both banks have good cover and abundance of trees and grass. The following tree species occur: *Searsia lancea, Acacia karroo, Olea europaea, Combretum erythrophyllum, Celtis africana*, etc. *Searsia lancea* is the most dominant. Dominant grasses are *Sporobolus pyramidalis*, *Sporobolus africanum, Themeda triandra* and *Polypogon monspeliensis*. There is very little exotic vegetation. Bank substrate consists of rocky material and soil.

WATER QUALITY

The ecological water quality at Site A2 ELAN-BESTEis of a category C (Moderate quality) with a moderate amount of organic content in the system (21.8%PTV) as reflected by the presence of dominant taxon *Gomphonema parvulum*.

The presence of dominant taxon *Fragilaria biceps* which points to elevated inorganic nutrients is also found at the site, as well as dominant taxon *Gomphonema minutum* associated with eutrophic waters but is not tolerant of more than moderate levels of pollution. Sub-dominant taxon *Nitzschia palea* points to minor organic nutrient inputs.

6.2.3 IMPACTS, THREATS AND MANAGEMENT PRIORITIES IN THE ELANDS RIVER

The main impacts resulting in the loss of ecological health include:

- Increased sedimentation and enrichment resulting in deterioration of substrate as habitat and loss of species, due to agricultural activities.
- Increased low flow, reducing flow depth classes, due to upstream dam and weirs and abstraction for agriculture.
- Loss of species richness/abundance, due to alien carp and bass present.

Management intervention is required to prevent further degradation of the resource. These include:

- Land-use management
- Management of point source discharges
- Co-operative management to control alien fish invasion.
- Implementation of minimum ecological water requirements, as set by the DWS.

6.3 ECOLOGICAL HEALTH OF THE HEX RIVER

Figure 6-11 graphically indicates the trend in the overall the ecological state of the Hex River from its source to the confluence with the Elands River over the 3-year monitoring. The results show a slight increase in the health of the river at the monitoring site from a low D category to an upper D category. This change could be as a result of the focus of monitoring changing from a site basis to a reach basis. This improvement in ecological category is also recorded in the fish (Figure 6-13), riparian vegetation (Figure 6-15) and instream ecological status (Figure 6-16) between 2013 and 2014.

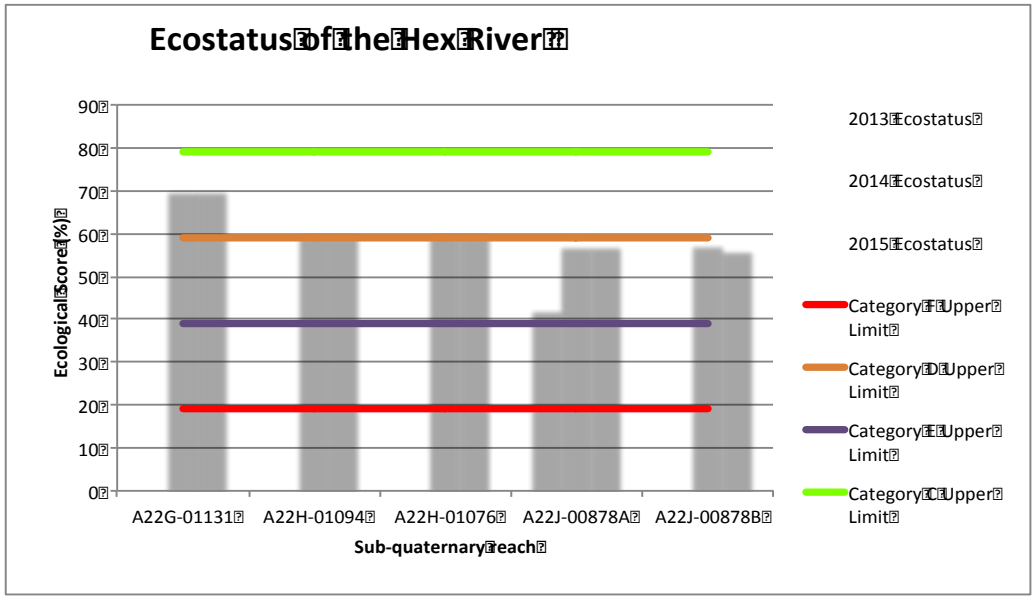


FIGURE 6-11. ECOSTATUS OF THE HEX RIVER FROM UPSTREAM (LEFT) TO DOWNSTREAM (RIGHT)

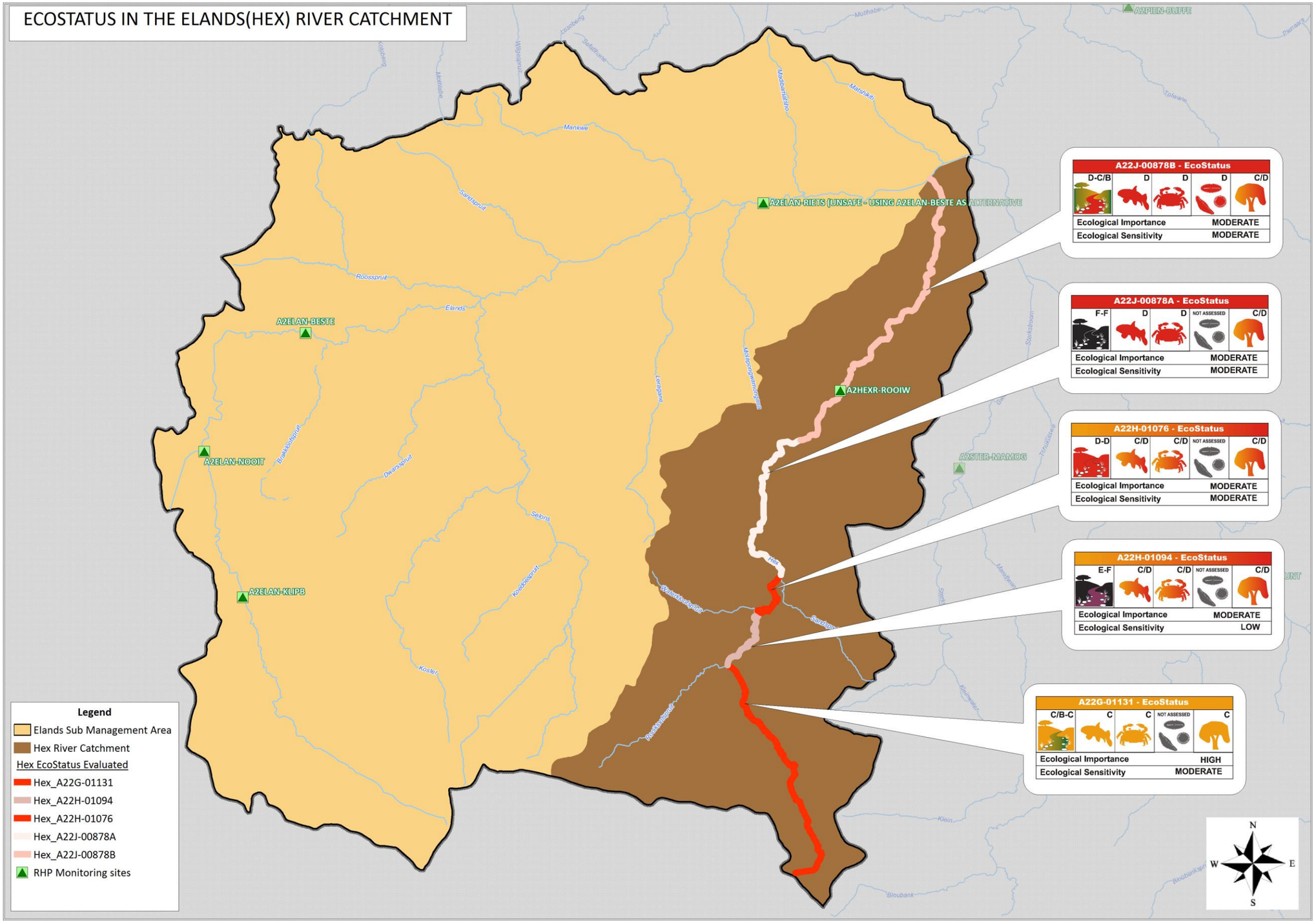


FIGURE 6-12. ECOLOGICAL STATUS OF THE HEX RIVER

Figure 6-12 provides an overview of the Hex River catchment indicating the Present Ecological State of the various biotic components and habitat integrity of the river reaches in the Hex River catchment. From this figure it can clearly be seen that the ecological health of the Hex River declines downstream of the Olifantsnek Dam. This is mainly due to agriculture, intensive mining and settlements in the area. The overall ecological health of the Hex River, decreases from a C ecological category to a largely modified, D ecological category, as the river flows lower into the catchment (Figure 6-12). There is a large loss of natural habitat and basic ecosystem functions and corresponding decrease in score for the fish, macro-invertebrates and the instream ecological category.

Other than at site A22J-00878B (A2HEXR-ROOIW), all other sub-quaternary reaches were assessed at a desktop level, based on the Habitat Integrity, using Google Earth imagery.

Monitoring at site A22J-00878B (A2HEXR-ROOIW), indicates a negative trend in the ecological condition of instream biota and habitat.

It is likely that the other reaches are also in a negative trend, however the desktop assessment is not sensitive enough to pick up these changes.

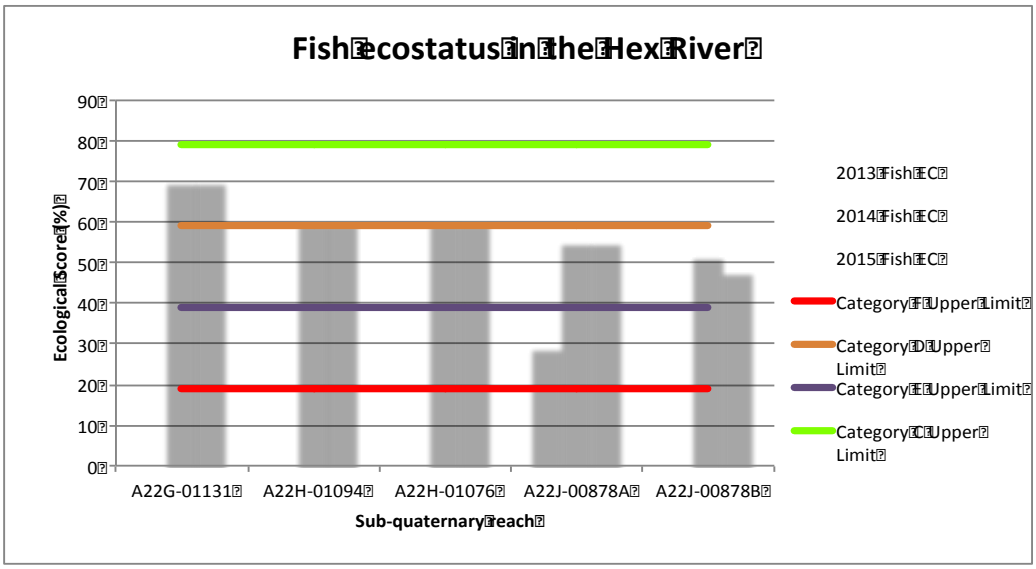


Figure 6-13. ECOLOGICAL STATE OF THE FISH IN THE HEX RIVER

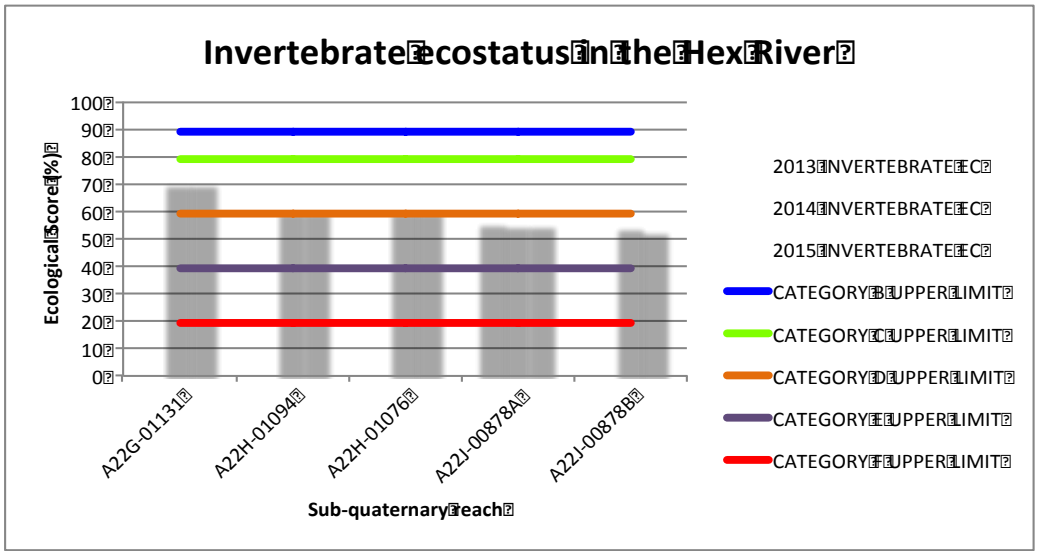


FIGURE 6-14. ECOLOGICAL STATE OF THE MACRO-INVERTEBRATES IN THE HEX RIVER

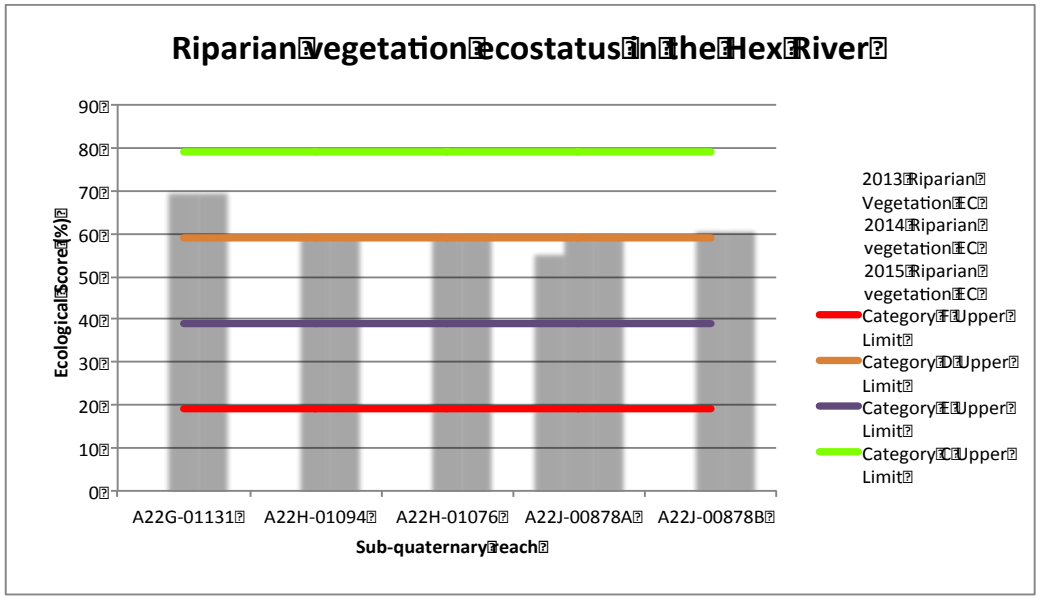


FIGURE 6-15. ECOLOGICAL STATE OF THE RIPARIAN VEGETATION IN THE HEX RIVER

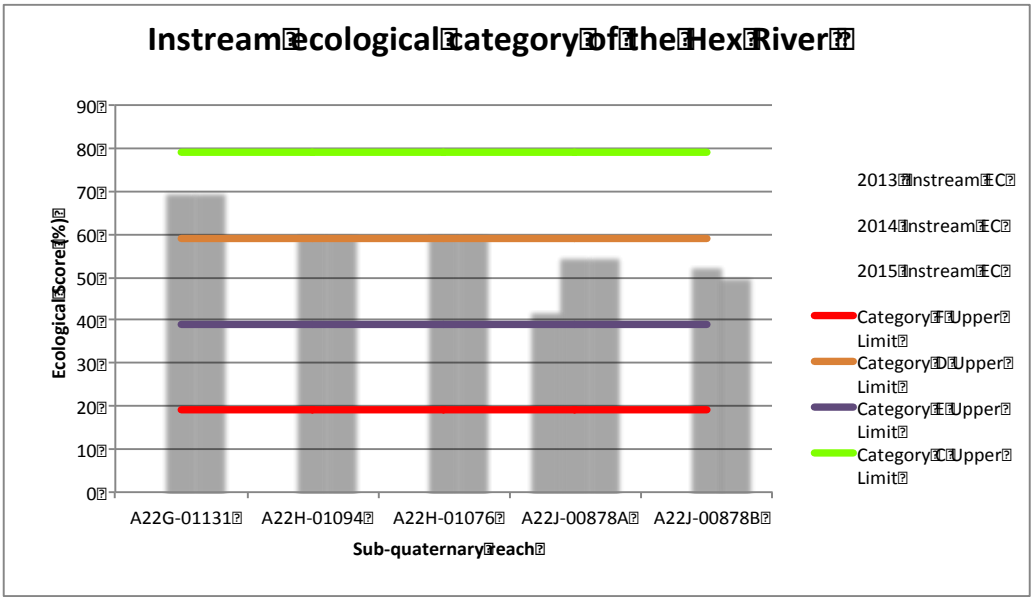


FIGURE 6-16. INSTREAM ECOLOGICAL HEALTH IN THE HEX RIVER

6.3.1 MONITORING RESULTS: REACH A22J-00878B (REPRESENTED BY A2HEXR-ROOIW)

	
upstream view August 2013	September 2014 (filamentous algae)
	
March 2015 (algae)	March 2015

FIGURE 6-17. SITE A2HEXR-ROOIW (A22J-00878B)

GENERAL DESCRIPTION

This site is situated on the Hex River, upstream of the R556 road bridge. Intensive mining, the town of Rustenburg and numerous settlements exist in this reach. The site is an existing EWR site, downstream of Bospoort Dam.

FISH

The site was sampled during August 2013, June and September 2014, and March 2015. An increase in the PES and EC was observed from 2013 (30%/E) to 2014 (51.6%D) due to a higher species diversity sampled and higher habitat diversity. A lower EC was recorded for March 2015 (47.65% D) due to low flows and the FROCs of species with a high affinity for fast flow (FS and FD) were reduced.

Algal growth on rocks and filamentous alga was very abundant during the surveys. The filamentous alga was very dense especially on the rocks resulting in habitat loss for species with a preference for substrate.

High siltation and sedimentation occur. Black decomposing organic rich silt was observed in sandy areas.

MACROINVERTEBRATES

Six data sets were used to run the MIRAI to derive an EC of D (52,6%), with data from 2006 to 2015. Changes to the EC were due to small changes in the flow modification metrics, with some changes to the habitat and water quality metrics. Overall, water quality is the most impacted, followed by the flow and habitat metrics.

All of the taxa with a high requirement for unmodified physico-chemical conditions are absent in this reach, except for >2spp Baetidae, which generally occurred at the expected abundance, however with a lower frequency of occurrence than expected under natural conditions. These sensitive taxa that are absent include Perlidae, Heptageniidae, Pyralidae and Hydropsychidae >2spp. Taxa that have a moderate requirement for unmodified physico-chemical conditions that are also absent in the reach include Psephenidae, Tricorythidae, Aeshnidae and Leptophlebiidae. The presence of taxa that require fast flowing water, i.e. >0.6m/s is largely impacted, whilst the occurrence of taxa showing a preference for loose cobbles is also largely impacted. The abundance of Simuliidae has increased considerably compared to what is expected under natural conditions, i.e. they now occur at a D abundance, whilst they were expected to occur at B abundance. Overall, the water quality driver is contributing the most to the impairment of the river in this reach, as is reflected in the absence of taxa with a high and moderate requirement for unmodified physico-chemical conditions.

RIPARIAN VEGETATION

Marginal Zone

Grass and reed dominated state. Vegetation extends into shallow water in places and also in and around sandy bars. Species in the area consist mainly of *Cyperus sexangularis* and *Phragmites australis*, etc. Deep scouring (bank collapse) is taking place with some deep bank erosion. Clumps of grasses, reeds and sedges are scattered throughout the system where habitat is available among the deposited material. Substrate consists of bedrock and soil. Some exotic pioneers are present (*Verbena bonariensis, Tagetes minutes, Ricinus communis,* etc.).

Non-marginal Zone

Tree and grass dominated state. Steep slopes due to bank collapse occur in places. The left bank consists of terraces with a good cover and abundance of trees and grass. The following tree species are present: *Searsia lancea, Acacia karroo, Ziziphus mucronata, Combretum erythrophyllum, Diospyros lycioides*, etc. *Searsia lancea* is the most dominant. Dominant grasses are *Sporobolus africanum, Themeda triandra* and *Polypogon monspeliensis*. Very little exotic vegetation is present. Bank substrate consists of rocky material and soil.

Overall the vegetation shows a negative trend and is currently in a C/D category.

WATER QUALITY

Recorded at site A2 HEXR-ROOIW is the dominant taxon *Cocconeis pediculus* which favours alkaline, eutrophic waters with elevated electrolyte content, including brackish conditions and is tolerant of moderate organic pollution. Other dominant taxa present are *Diatoma vulgaris* and *Cocconeis placentula var. placentula* which, combined with C. pediculus, points to impacts from agricultural activities, mainly organic and inorganic nutrients, and electrolyte enrichment from fertiliser runoff. South African studies have linked *D. vulgaris* specifically to freshwaters with elevated levels of phosphate-phosphorus. This diatom species is routinely found in high abundances below Bloemhof Dam, which occurs in an irrigated agricultural region. At Site HexR-Rooiw, the presence of dominant taxon *Fragilaria ulna var.acus* points to an elevation of inorganic nutrients. For reasons mentioned above, the biological water quality at this site should be lowered from the OMNIDIA assigned category B (good quality) to a more suitable category D (Poor quality).

6.3.2 IMPACTS, THREATS AND MANAGEMENT PRIORITIES IN THE HEX RIVER

The main impacts resulting in the loss of ecological health include:

- Poor water quality affecting habitat availability and condition and also species composition
- Flow modification, due to dams and water abstraction
- Nutrient enrichment from agricultural activities, such as use of fertilisers and cattle watering at the river
- Mining activities
- Impacts from settlements

Management intervention is required to prevent further degradation of the resource. These include:

- Management of land-use practices
- Control and management of abstraction of water
- Awareness creation on effects of human waste to the water resources.

7 RESULTS IN THE APIES/PIENAARS SUB-AREA

The Apies / Pienaars sub-management area comprises the Apies River catchment, the Pienaars River catchment and the catchment of the Moretele and Tlholwe rivers down to its confluence with the Crocodile

River. The Apies River joins the Pienaars River to the north of Hammanskraal. The Apies River drains the Pretoria CBD, parts of the central-eastern suburbs and most of the western Pretoria industrial and urban areas. Increased high surface water runoff is channelled into the Apies River, including the Bon Accord Dam from these areas. The Dam is experiencing high levels of eutrophication.

The Pienaars River joins the Crocodile River just below the confluence of the Crocodile and Elands rivers. Roodeplaat Dam and Klipvoor Dam are the major dams in the sub-catchment while Pretoria in the southern part and Bela-Bela, situated in the northern part of the sub-catchment, are the major towns. The upper and middle reaches of this sub-management area in particular are densely settled.

The Pienaars River drains the area from Pretoria northwards to the Waterberg Mountains near the town of Bela-Bela. All the main rivers are perennial and their flows are supplemented by substantial discharges of treated domestic and industrial effluent. Flows in these rivers are also enhanced by water imported from the Vaal River system to the south of Johannesburg, which is used principally for domestic and industrial water supplies prior to treatment and discharge.

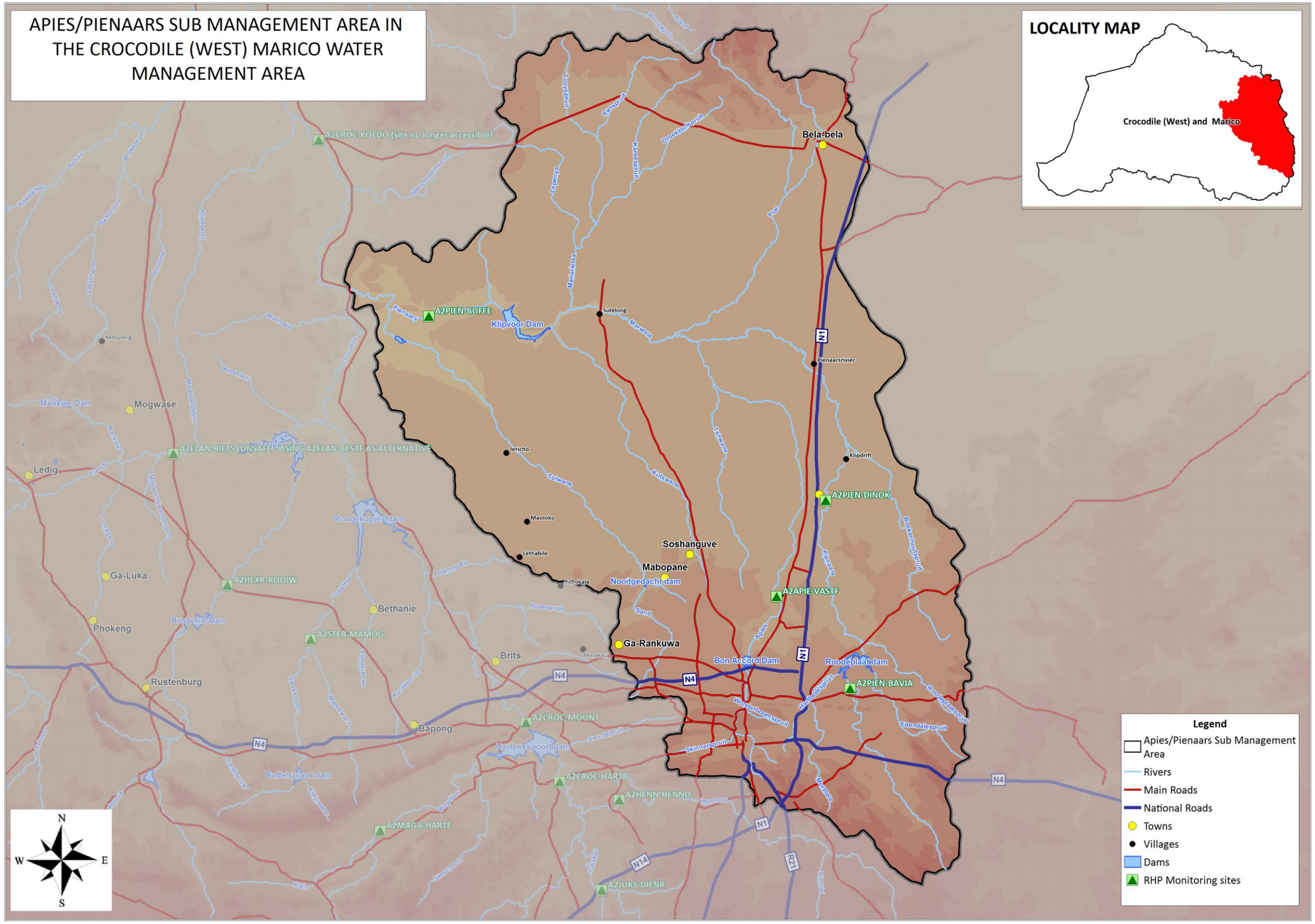


FIGURE 7-1. OVERVIEW OF THE APIES/PIENAARS SUB-MANAGEMENT AREA

7.1 RIVER HEALTH MONITORING SITES IN THE APIES/PIENAARS SUB-AREA

Four monitoring sites were selected in the Apies/Pienaars sub-area. These sites are representative of the reaches in which they are located. Table 7-1 provides the sub-quaternary reaches within the Apies/Pienaars Sub-Area and the River Health Monitoring Sites that have been sampled over the project period.

TABLE 7-1. SUB-QUATERNARY REACHES AND RIVER HEALTH MONITORING SITES IN THE APIES/PIENAARS SUB-AREA

MONITORING SITE	SQR REACH	RIVER NAME	SQR NUMBER	LATITUDE	LONGITUDE
	A23D-01117	Apies	AP01.00		
	A23D-01105	Apies	AP02.00		
	A23E-01071	Apies	AP03.00		
A2APIE-VASTF	A23F-00827	Apies	AP04.00	-25.53736	28.23581
A2PIEN-BAVIA	A23A-01056	Pienaars	P01.00	-25.66802	28.35099
	A23B-01034	Pienaars	P03.00		
A2PIEN-DINOK	A23B-00896	Pienaars	P04.00	-25.40084	28.31269
	A23C-00751	Pienaars	P05.00		
	A23J-00793	Pienaars	P06.00		
	A23J-00710	Moretele	P07.00		
	A23J-00736	Moretele	P08.00		
	A23J-00717	Pienaars	P09.00		
A2PIEN-BUFFE	A23L-00706	Pienaars	P10.00	-25.13958	27.69114

7.2 ECOLOGICAL HEALTH OF THE PIENAARS RIVER

The overall ecological health of the Pienaars River is moderately modified. There is a moderate loss of natural habitat, biota and basic ecosystem functions. The river is in a mid to low ecological category C, except for the upper most reach of the river, which is in an upper D category as can be seen from Figure 7-2.

Monitoring of site A2PIEN-BUFFE, within reach A23L-00706, indicates a decrease in the ecological health of the reach over the 3 years of sampling. This site showed a decrease in instream health (Figure 7-7) and the macro-invertebrates (Figure 7-5) between 2013 and 2014, which was reflected in a decrease in fish score between 2014 and 2015 (Figure 7-4).

Figure 7-3, indicates that over the 3 years the ecological condition of the various reaches have been deteriorating, even though slightly. If this negative trend continues, the river can deteriorate into a D category.

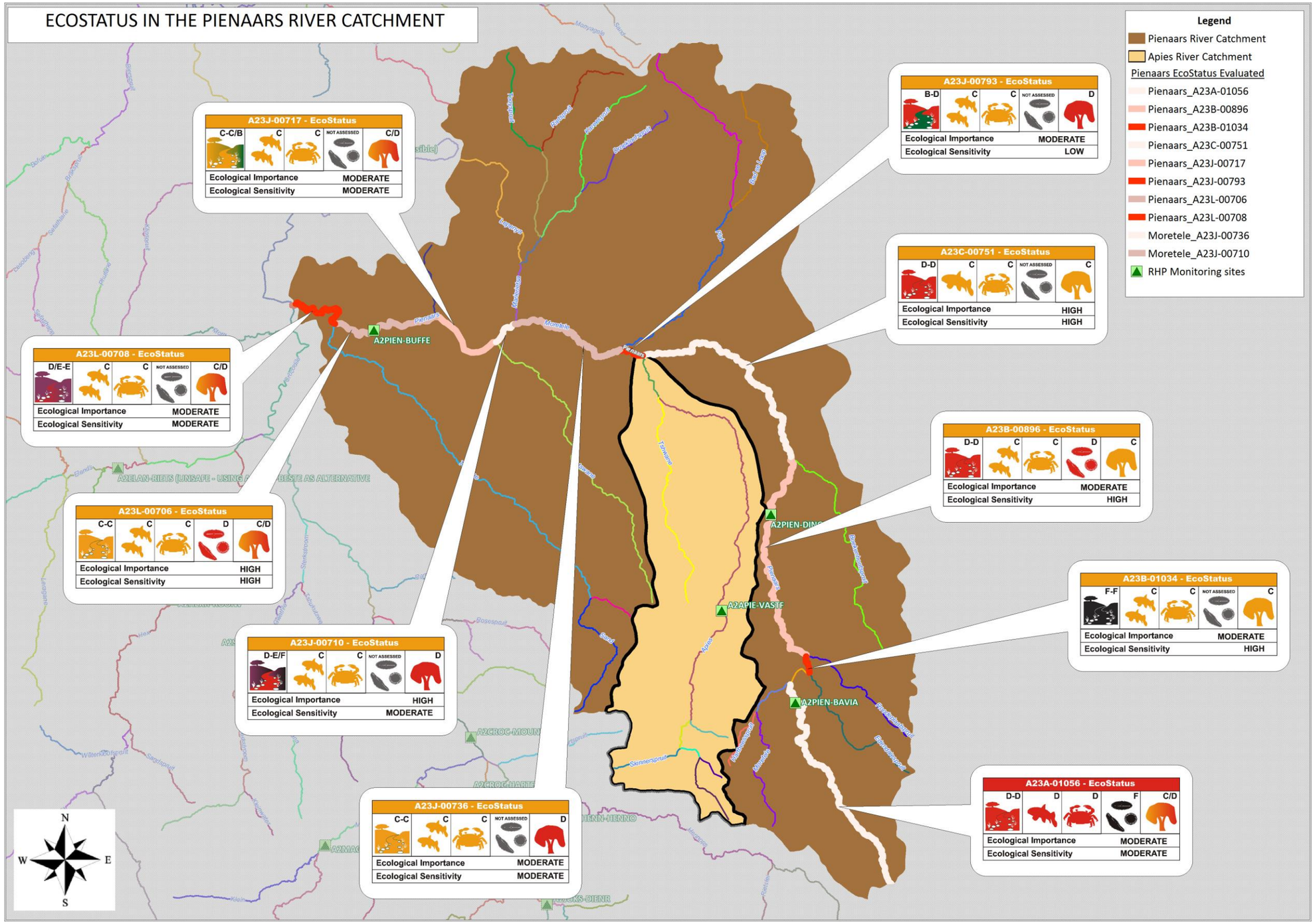


FIGURE 7-2. ECOLOGICAL STATE OF THE PIENAARS RIVER CATCHMENT

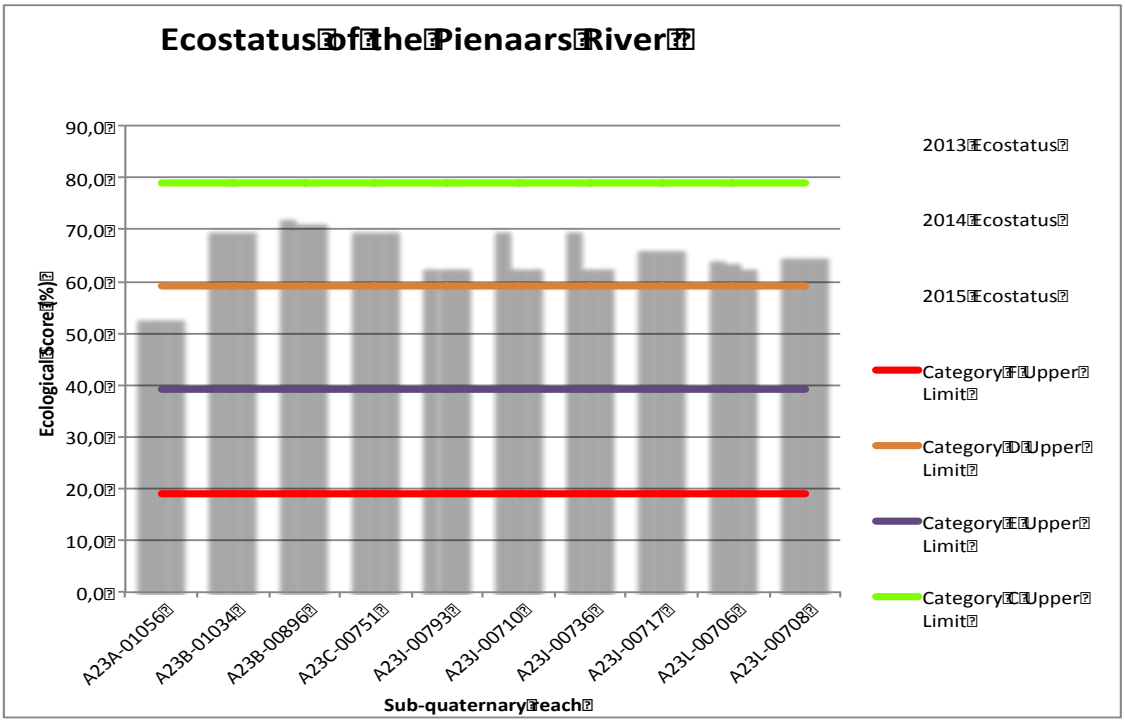


FIGURE 7-3. ECOSTATUS OF THE PIENAARS RIVER FROM UPSTREAM (LEFT) TO DOWNSTREAM (RIGHT)

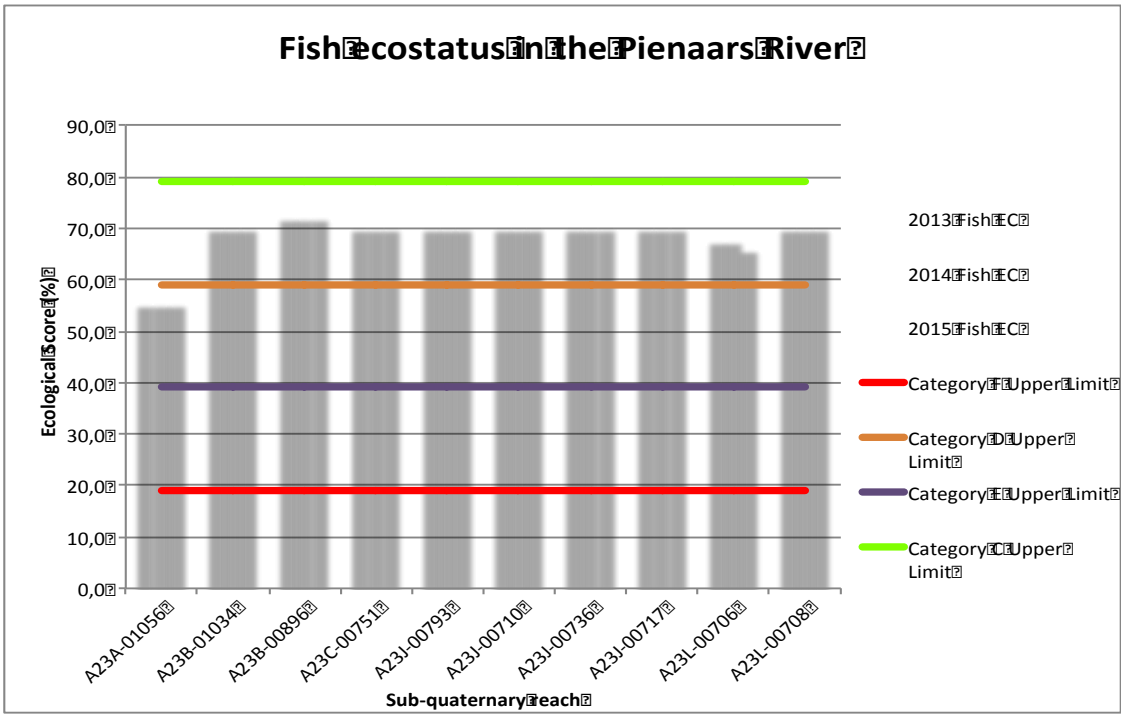


FIGURE 7-4. ECOLOGICAL STATE OF THE FISH IN THE PIENAARS RIVER

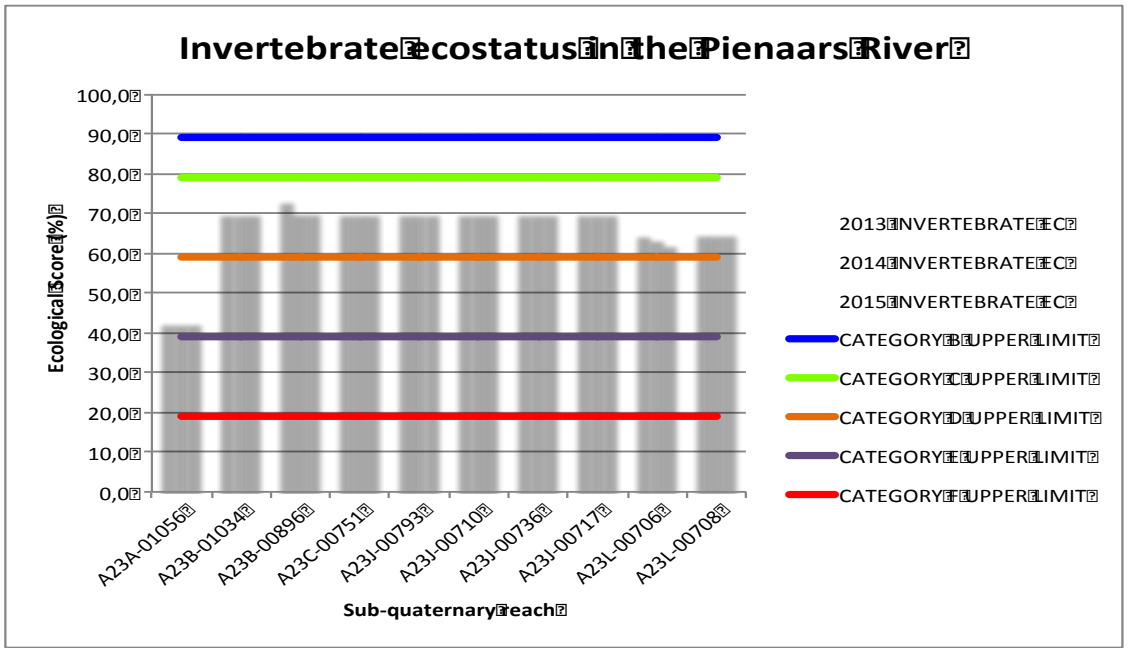


FIGURE 7-5. ECOLOGICAL STATE OF THE MACRO-INVERTEBRATES IN THE PIENAARS RIVER

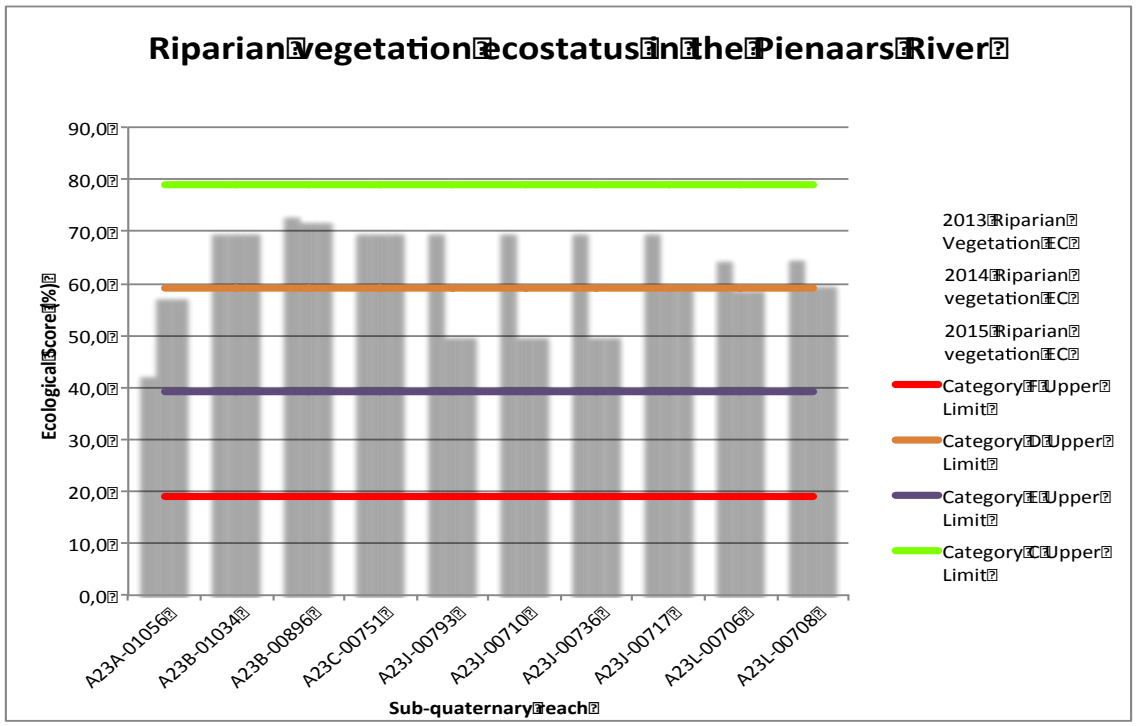


FIGURE 7-6. ECOLOGICAL STATE OF THE RIPARIAN VEGETATION IN THE PIENAARS RIVER

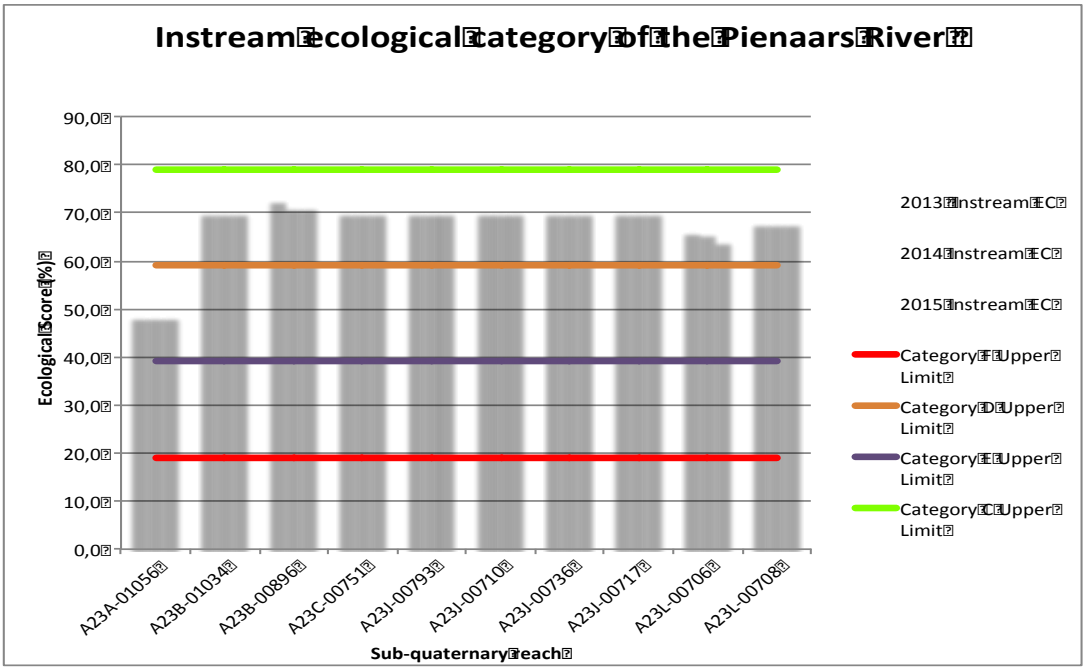


FIGURE 7-7. INSTREAM ECOLOGICAL HEALTH IN THE PIENAARS RIVER

7.2.1 MONITORING RESULTS: REACH A23A-01056 (REPRESENTED BY A2PIEN-BAVIA)

	
August 2013	September 2014
	
March 2015	March 2015

FIGURE 7-8. A2PIEN-BAVIA (A23A-01056)

GENERAL DESCRIPTION

This site is situated on the Pienaars River, downstream of the Baviaanspoort Wastewater Treatment Works, downstream of Mamelodi, upstream of the Roodeplaat Dam. The upper section of the reach has some small instream dams and is less impacted, with plots and associated homesteads, numerous roads and bridges and sand mining occurring. The site is immediately downstream of a weir.

FISH

Fish surveys were conducted during April and August 2013, and June 2014. High flow occurred during September 2014, although no habitat alteration was observed. The site was visually surveyed during March 2015 and habitat conditions remained the same, but sewage input from upstream sources posed a health risk for sampling at this site and fish sampling was not conducted during March 2015.

The site seems to have remained constant in its PES and EC from 2013-2015 (55.2% / D).

Sewage input and enrichment seem to be the major impacts for this reach.

All the expected fish species are expected to still be present within this SQ Reach although the Frequency of Occurrence (FROC) of some species has been reduced slightly from reference conditions. Species with a preference for substrate (rocks and rocky habitat etc.) received reduced FROC's, as there is siltation/sedimentation and algae growth present at the site (BMAR). Enrichment is a problem, and this also influenced the FROC's of species. Sewage effluent evident at the site will deteriorate water and habitat quality (excessive algal growth and siltation) for fish. Urban run-off and water pollution will also influence the FROC's of species in terms of water quality modification. Some fish were observed to have black spot indicating modified water quality. Dams, weirs, and water abstraction (flow modification) leading to low water levels and fewer events for flushing sediments will result in habitat deterioration and species loss and will also influence species migration. Dams and weirs causing flow modification and lower water levels also influence species with a preference for water column negatively (BMAR, and BPAU).

MACROINVERTEBRATES

Six data sets were used to run the MIRAI to derive an EC of D (42.6%), with data from 2012 to 2013, from various sites within the reach. No SASS was conducted at the site due to high flow present during both sampling surveys in 2014, as well as in 2015. Furthermore, sewage was present at the site which is considered a health risk.

The water quality metric is the most impacted at 25.6%, followed by the flow modification and habitat metrics.

All taxa with a high and moderate requirement for unmodified physico-chemical conditions, except for 1 individual Gerridae, were absent. The presence of taxa with a preference for high, moderate and slow flowing water is highly impacted.

RIPARIAN VEGETATION

Marginal Zone

Grass and sedge dominated state. The following species occur in this zone: *Cyperus sexangularis, Sporobolus africanus, Panicum natalensis, Veronica anagallis-aquatica, Phragmites australis*, etc. Vegetation cover is limited due to eroded areas with bare patches. This zone is steep in places due to erosion (scouring). Its substrate consists of soil. Exotic vegetation occurs in the form of *Tagetes minutes, Melia azedarach, Arundo donax, Solanum mauritianum*, *Pennisetum clandestinum*, etc. Indigenous trees such as *Combretum erythrophyllum, Celtis africana, Searsia lanceolata*, etc. are present, resulting in a shading effect on the water.

Non-marginal Zone

Tree and grass dominated state. Trees and shrubs provide reasonable cover, with abundance being low. The following grass species provide good vegetation cover: *Sporobolus africana, Panicum natalensis, Eragrostis megaphylla*, etc. This zone is steep at the beginning and then levels out and includes high flow channels. Trees and shrubs such as *Combretum erythrophyllum, Gymnosporia buxifolia*, *Diospyros lycioides*, etc. are present. Bank substrate consists of sandy material. Soil has been disturbed due to historic clearing activities. Diggings occur for waste disposal use. Exotic species dominating this zone (especially on the island) include the creeper *Ipomoea purpurea*, *Morus alba, Tithonia multiflorum, Persicaria lapathifolia*, *Ulmus parviflora,* etc. The climber *Ipomoea purpurea* has increase extensively on the right bank's non-marginal zone.

The overall vegetation score is a C/D with a negative trend.

WATER QUALITY

The water quality at Site A2 PIEN-BAVIA which is of an Ecological Category E (bad quality) with a high (organic) pollution tolerant value %PTV (71%) which implies that the site is heavily impacted by organic material. Recorded at this site are the high prevalence of taxon *Sellaphora seminulum* and the presence of dominant taxon *Diadesmis confervacea*, species found in a range of waters including eutrophic, electrolyte-rich and extremely polluted waters. The presence of dominant taxon *Fragilaria ulna var.acus* points to an elevation of inorganic nutrients.

7.2.2 MONITORING RESULTS: REACH A23B-00896 (REPRESENTED BY A2PIEN-DINOK)

	
April 2013	September 2014 (Filamentous algae)

	
March 2015	March 2015

FIGURE 7-9. A2PIEN-DINOK (A23B-00896)

GENERAL DESCRIPTION

This site is situated on the Pienaars River, in Dinokeng, downstream of a high road bridge, with a low water bridge occurring at the site and the Roodeplaat Dam approximately 28km upstream from the site. The land use in this reach consists mostly of open areas and plots, with some irrigated agriculture and dry land agriculture in the upper section of the reach.

FISH

Fish surveys were conducted during April 2013, June and September 2014. A visual survey was conducted during August 2013 documenting the habitat availability for fish. During March 2015 a visual survey was conducted as the flows were high and the visibility very low for sampling. The PES and EC scores derived from the FRAI are expected to remain stable (as derived for 2013 to 2015), in a C category.

All the expected fish species are expected to still be present within this SQ Reach although the Frequency of Occurrence (FROC) of some species has been reduced slightly from reference conditions.

Enrichment is evident at this site due to extensive filamentous algal growth observed during the surveys and the presence of dense free living algae in the water column. This affects the abundance and occurrence of species. Species with a preference for substrate (rocks and rocky habitat etc.) received reduced FROC's, as there is siltation/sedimentation and algae growth present at the site (*Chiloglanis pretoriae*, and *Labeobarbus marequensis*). Enrichment, urban run-off and water pollution also influenced the FROC's of species which are intolerant to moderately intolerant to WQ modification.

Some fish were observed to have black spot indicating modified water quality.

Large dams, weirs, and water abstraction (flow modification) leading to low water levels and fewer events for flushing sediments will result in habitat deterioration and species loss and influence species with a preference for water column negatively, such as *Labeobarbus marequensis, Mesobola brevianalis and Barbus paludinosus.* Dams and weirs will also influence species migration.

MACROINVERTEBRATES

Four data sets were used to run the MIRAI to derive an EC of C (70.2%), with data from 2007 to 2014. The water quality metric is the most impacted at 65.5%, followed by the flow modification and habitat metrics. No sampling was conducted in 2015 due to high flow, hence the EC remained the same as in 2014. Many taxa with a high and moderate requirement for unmodified physic-chemical conditions are absent, whilst those that do occur, generally occur at the expected abundances and frequencies of occurrence. The presence of taxa that show preference for loose cobbles and vegetation is impacted the most of the habitat modification metrics.

RIPARIAN VEGETATION

Marginal Zone

Grass and sedge dominated state. Good vegetation cover exists, with trees and shrubs also contributing to shading of this zone (**Error! Reference source not found.**)?. Zone is steep in places with fragments of erosion occurring (scouring and bank slumping). The substrate consists of soil. Cover, abundance and species composition is good. Grasses and sedges common in this zone include *Typha capensis, Schoenoplectus brachyceras, Phragmites australis, Cyperus sexangularis, Eragrostis curvula, Cymbopogon plurinodis, Panicum maximum*, etc. Not much exotic vegetation occurs; species such as *Tagetes minutes, Melia azedarach*, etc. are present. Indigenous trees such as *Acacia ataxacantha*, *Carissa bispinosa*, *Salix mucronata*, *Gomphostigma virgatum*, *Combretum erythrophyllum* and *Celtis africana* are present.

Non-marginal Zone

This zone is dominated by trees, shrubs and grass (**Error! Reference source not found.**)?. There is good cover, abundance and species composition of trees and shrubs. Species common in this zone include *Combretum erythrophyllum, Gymnosporia buxifolia, Diospyros lycioides*, *Searsia lancea*, *Ziziphus mucronata, Carissa bispinosa, Ozoroa paniculosa*, etc. The upper zones starts off steep and then level out, and include a high flow channel and grass species such as *Eragrostis megaphylla, Panicum coloratum, Cymbopogon plurinodis,* etc. Not much exotic vegetation occurs: *Morus alba, Melia azedarach, Eucalyptus grandis, Pyracantha angustifolia,* etc. The bank substrate consists of sandy material. Many wild animal signs such as pig diggings, spoor and droppings are visible.

The overall vegetation score for the reach is a C, stable state.

WATER QUALITY

The water quality at Sites A2PIEN-DINOK is, according to OMNIDIA, classified as an Ecological quality B/C (Good quality). Yet the species compositions at the site is dominated by taxon *Cocconeis placentula var. placentula* a species indicative of heavy nutrient enrichment when prevalent. Also recorded is dominant *Amphora pediculus, Navicula cryptotenelloides* and sub-dominant *Navicula tripunctata* and *Navicula gregaria* which combined with *Cocconeis placentula var. placentula*, suggest impacts related to eutrophication, often a result of fertiliser runoff and urban wastewaters. For reasons outlined above, the water quality at this site should be allocated a category D (Poor quality).

7.2.3 MONITORING RESULTS: REACH A23L-00706 (REPRESENTED BY A2PIEN-BUFFE)

	
August 2013 - Note the green colour of the water	June 2014
	
September 2014 (Filamentous algae present)	March 2015

FIGURE 7-10. A2PIEN-BUFFE (A23L-00706)

GENERAL DESCRIPTION

This site is situated on the Pienaars River, approximately 14 kilometres downstream of Klipvoor Dam, near to a rural settlement. The surrounding area is open, with some traces of historic dry land agriculture in the upper sections of the reach.

FISH

The site was surveyed during April and August 2013, June and September 2014, and March 2015. The PES and EC (67.4% / C for 2013-2014 and 65.8% / C for March 2015) remained fairly stable during all the surveys, although a lower flow was present during March 2015 which has reduced the FROCs of species with an affinity for fast flow, and which resulted in the lower recorded PES and EC for March 2015.

All the expected fish species are expected to still be present within this SQ Reach although the Frequency of Occurrence (FROC) of some species has been reduced slightly from reference conditions. One additional species were sampled similar to *Barbus motebensis*.

Reduced FROC's were given mostly for species with a preference for SD and SS habitats, as they were sampled in low numbers or not at all (*Barbus paludinosus, Barbus unitaeniatus, Mesobola brevianalis, Tilapia sparrmanii*). There seems to have been a reduction in these habitats under the conditions experienced at time of survey.

Species with a preference for substrate (rocks and rocky habitat etc.) such as *Chiloglanis paratus, Labeo cylindricus and Labeo molybdinus* also received reduced FROC's, as there is siltation/sedimentation and abundant filamentous algae growth present at the site. The water is enriched with a green colour at times, indicating algal growth in the water column. Enrichment will play a role in the abundance and occurrence of species. Water quality is not optimal at the site and enrichment seems to be a problem, and this also influenced the FROC's of species which are moderately intolerant to WQ modification (these include *Chiloglanis paratus, Labeo cylindricus and Labeo molybdinus*, and *Barbus motebensis*).

MACROINVERTEBRATES

Eight data sets were used to run the MIRAI to derive an EC of C (62.2%), with data from 2006 to 2015. The most impaired metric is that of water quality, followed by flow and instream habitat modification. Taxa that have a high requirement for unmodified physico-chemical conditions and that are absent in the reach include Perlidae, Pyralidae and Heptageniidae. Some of the taxa preferring fast flowing water, i.e. >0.6m/s include Psephenidae and Philopotamidae were absent in this reach. Tricorythidae showed a decrease in abundance as well as a decrease in their frequency of occurrence over time. The occurrence of taxa preferring cobbles and vegetation are largely impacted, whilst those taxa preferring bedrock and the water column are minimally impacted. Overall, the water quality driver seems to be contributing the most to the impairment of the river in this reach, as is reflected in the absence of taxa with a high and moderate requirement for unmodified physico-chemical conditions.

RIPARIAN VEGETATION

Marginal Zone

Trees and shrubs dominate, with patches of grass (include some sedges). *Phragmites* and *Typha* clumps occur, more so on the island. Bare patches occur due to bank scouring, large and small stock drinking, and water collection activities. There is little grass and sedge cover on the left bank as a result of bank scouring. Woody cover and abundance is good. Higher grass and sedge abundance, as well as greater grass and sedge species composition is expected. Substrate of zone consists mainly of sandy and rocky material. Scouring exposes roots of trees and shrubs. Zone is dominated by *Acacia gerrardii, Combretum erythrophyllum, Phragmites australis, Paspalum distichum, Cynodon dactylon, Cyperus sexangularis*, Juncus effusus, Cyperus marginatus, etc. Hydrophytic vegetation such as *Nasturtium officinalis* and Veronica *anagalis-aquatica* also occurs. Impacts comprise mainly armouring, scouring, trampling, grazing, etc. Water quality is enriched with a strange green colour. The dam upstream could have contributed to an armouring effect.

Non-marginal Zone

Tree and shrub dominated state. This zone is well covered with vegetation, with good abundance. Little exotic vegetation is present. Extreme tree and shrub cover has resulted in less undergrowth. Species common in this

zone include *Combretum erythrophyllum, Salix mucronata, Diospyros lycioides, Cynodon dactylon, Urochloa panicoides*, etc. Indications of terrestrialization occur due to *Dichrostachys cinerea* and *Gymnosporia senegalensis* occurring. Bank substrate consists of alluvial material (sandy). The shading effect of trees result in little groundcover in places. Grazing and trampling have resulted in less grass cover and signs of erosion are visible. Water quality is eutrophic and dam upstream creates armouring effect.

The overall vegetation score for the reach is a C/D with a negative trend.

WATER QUALITY

The water quality at A2PIEN-BUFFE is, according to OMNIDIA, classified as an Ecological quality B (good quality). Yet the species compositions is dominated by taxon *Cocconeis placentula var. placentula* (almost 100%), a species indicative of heavy nutrient enrichment when prevalent. For this reason, the water quality at this site should be allocated a category D (Poor quality).

7.2.4 IMPACTS, THREATS AND MANAGEMENT PRIORITIES IN THE PIENAARS RIVER

The main impacts relating to the fair ecological condition of the Pienaars River include:

- Sedimentation and habitat loss due to agricultural and urban runoff
- Loss of habitat and substrate quality, due to increased low flows and reduced freshets for flushing the sediments
- Reduced habitat and water quality, due to poor water quality from WWTW and land use practices resulting in filamentous algae.

Management intervention is necessary to prevent further degradation of the ecological health of the system. Management priorities include:

- Management of land-use practices
- Implementation of the ecological Reserve
- Management of discharges into the system
- Eradication of exotic vegetation, such as Eucalyptus grandis and Glenditsia tricanthos
- Burning programmes should include the riparian zones
- Exclude roads from the riparian areas.

7.3 ECOLOGICAL HEALTH OF THE APIES RIVER

The overall health of the Apies River decreases from a largely modified, D ecological category to a D/E (unsustainable) category as the river flows lower into the catchment, as can be seen from Figure 7-11. The

integrated habitat ecostatus (Figure 7-11) and the vegetation (Figure 7-16) is in a very poor to unsustainable condition.

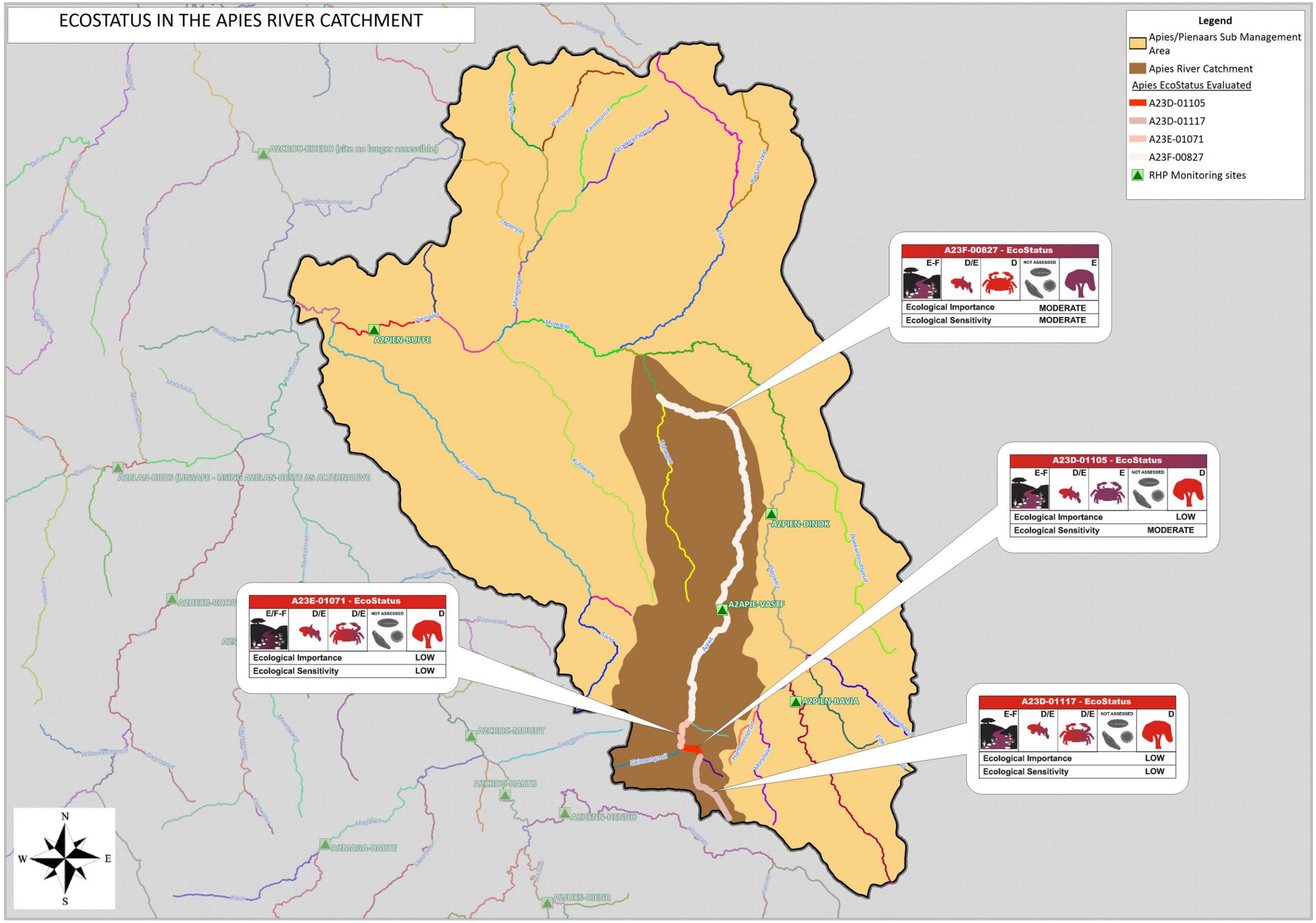


FIGURE 7-11. ECOLOGICAL STATE OF THE APIES RIVER CATCHMENT

From Figure 7-12, the site monitored, A2APIE-VASTF, in reach A23F-00827, indicates a deterioration in the ecological health of the river reach over the 3 years of monitoring. The current state of the reach is in an unsustainable state and if management action is not taken, the system will fail and its ability to recover will be severely compromised.

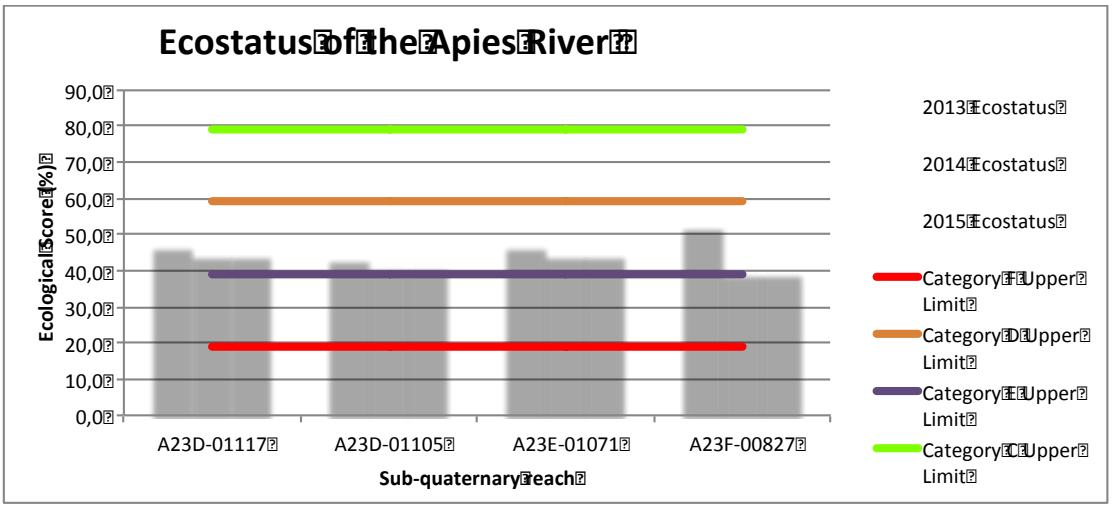


FIGURE 7-12. ECOSTATUS OF THE APIES RIVER FROM UPSTREAM (LEFT) TO DOWNSTREAM (RIGHT)

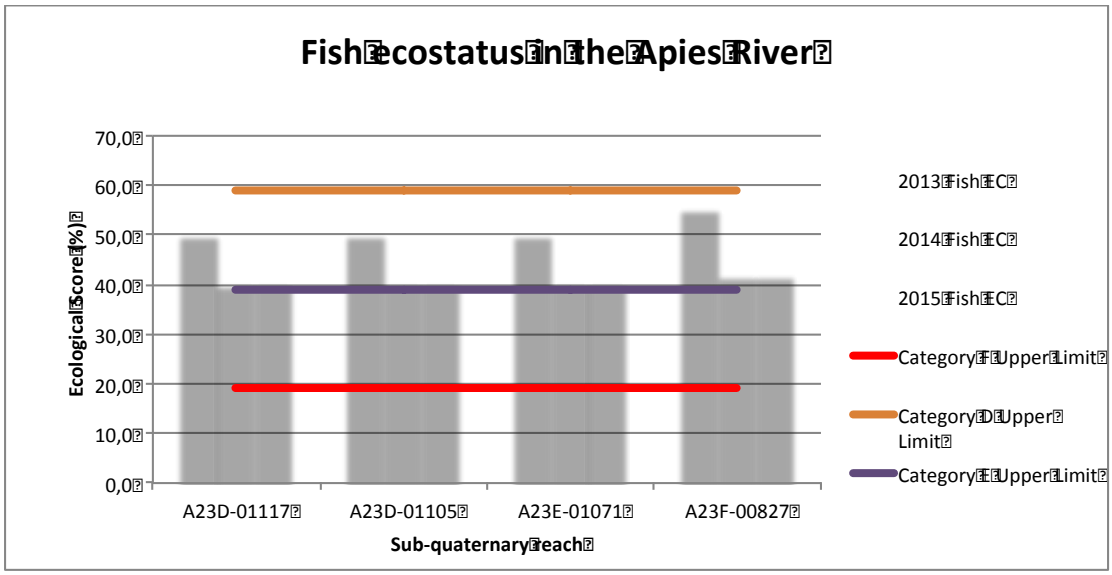


FIGURE 7-13. ECOLOGICAL STATE OF THE FISH ON THE APIES RIVER

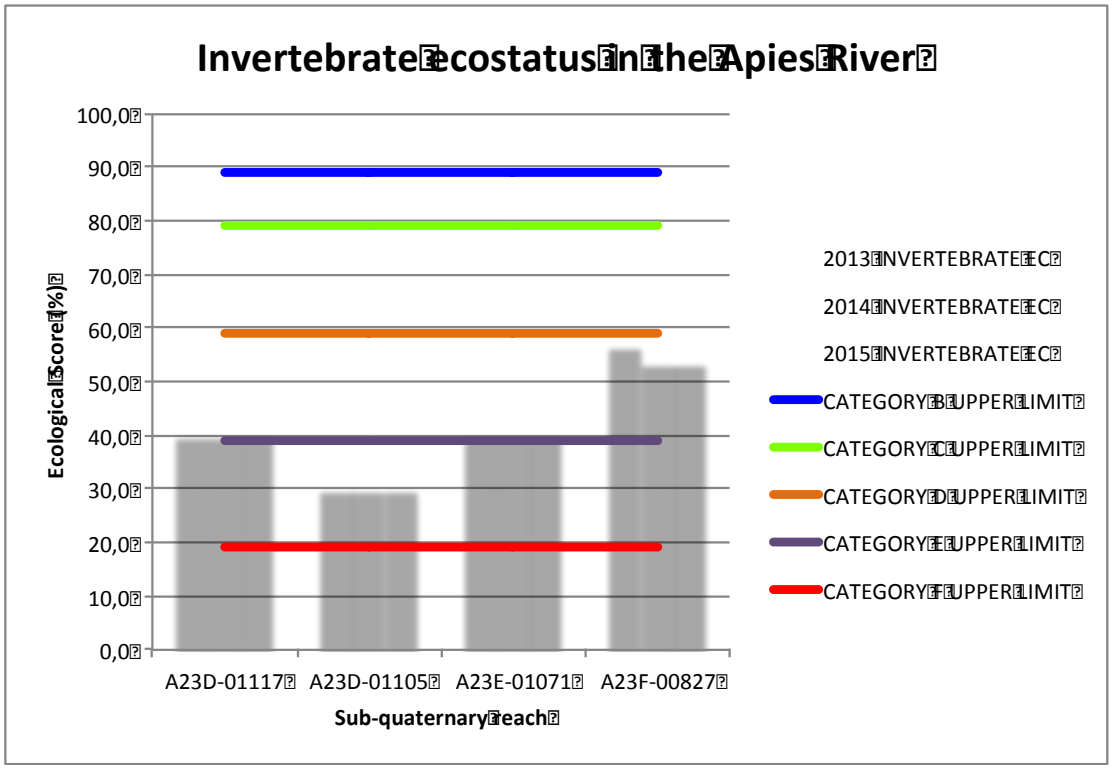


FIGURE 7-14. ECOLOGICAL STATE OF THE MACRO-INVERTEBRATES IN THE APIES RIVER

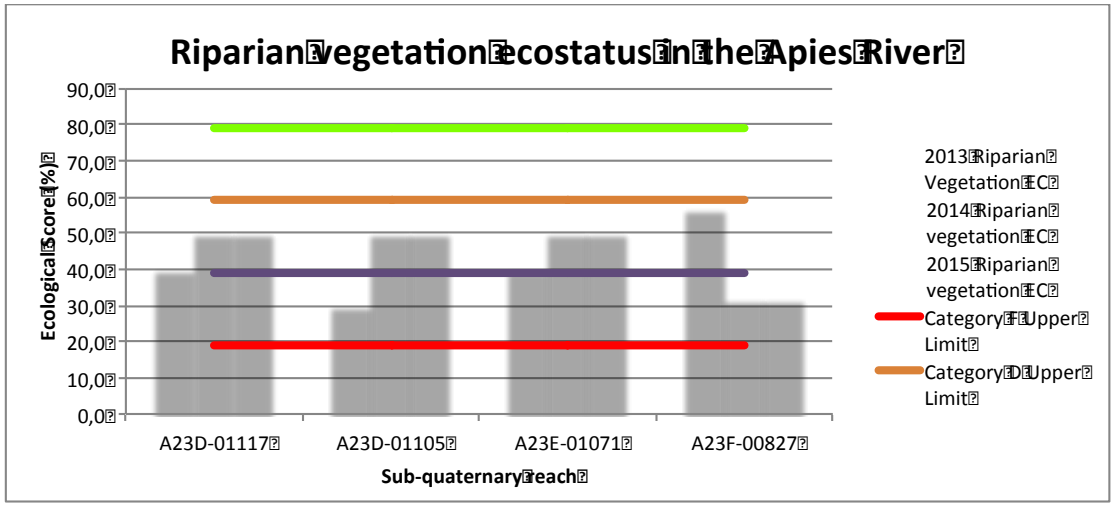


FIGURE 7-15. ECOLOGICAL STATE OF THE RIPARIAN VEGETATION IN THE APIES RIVER

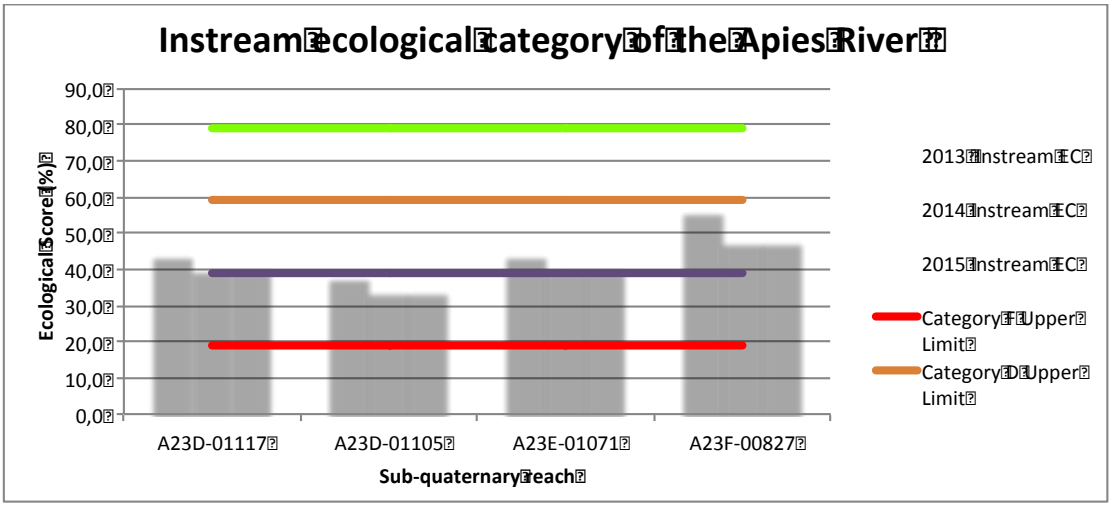


FIGURE 7-16. INSTREAM ECOLOGICAL HEALTH IN THE APIES RIVER

7.3.1 MONITORING RESULTS: REACH A23F-00827 (REPRESENTED BY A2APIE-VASTF)

	
August 2013	June 2014 (indicates sediment build up in slow shallow habitats)
	
September 2014	March 2015

FIGURE 7-17. A2APIE-VASTF (A23F-00827)

GENERAL DESCRIPTION

This site is situated on the Apies River, downstream of Tshwane, with numerous roads, small instream dams, a power station, Hammanskraal, wastewater treatment works, small plots, intense agricultural activities, channel incision and Bon Accord Dam as impacts. Exotic vegetation is dominant at the site. The site consists of vast bedrock sections. This site forms part of a bigger floodplain area with wetland habitat adjacent to the riparian zone. Immediate impacts include old infrastructure such as a broken cement weir, dumped rubble, fencing material and tree cutting with several tree stumps visible.

FISH

Increased sewage pollution was observed during June and September 2014. Slow or quiet water areas had a serious black organic silt build-up (knee deep in areas). During the March 2015 conditions have not changed, and sampling at the site is considered as a health risk.

Very few fish were sampled during June and September 2014. Habitat diversity for sampling fish is low, consisting of mainly bedrock (2015). More habitat is available downstream, but the flow is too fast and deep for sampling.

The EC and PES has declined from August 2013 to September 2014, and will have a continued negative trend if current conditions prevails (black silt deposits of organic origin most probably due to WWTWs upstream). A sewage odour was detected at the site during all the surveys. Habitat and site conditions have not changed during the March 2015 survey.

The PES and EC has declined from 55.2% / D during 2013 to 41.9% / D/E during 2014. The PES and EC remained constant from 2014 to March 2015 (41.9% / D/E) due to current conditions prevailing.

All the expected fish species are expected to still be present within this SQ Reach although the Frequency of Occurrence (FROC) of some species has been reduced slightly from reference conditions.

There will be a long term negative trend in the fish species PES due to the presence of two alien fish species *Gambusia affinis* and *Cyprinus carpio* which have a negative impact in native fish species.

Species with a preference for substrate (rocks and rocky habitat etc.) received reduced FROCs, as there is siltation/sedimentation and algae growth present at the site. Enrichment, urban and agricultural run-off and water pollution will also play a role in the abundance and occurrence of species, influencing the FROCs of species which are intolerant or moderately intolerant to WQ modification.

Large dams, weirs, and water abstraction (flow modification) leading to low water levels and fewer events for flushing sediments will result in habitat deterioration and species loss and influence species migration.

Organic pollution from upstream WWTWs is serious at the site and will result in species loss.

MACROINVERTEBRATES

Fifteen data sets were used to run the MIRAI to derive an EC of D (53.6%), with data from 2012 to 2014, from various sites within the reach. No sampling was conducted in 2015 due to sewage in the river, impacting on the macroinvertebrates in terms of water quality, as well as impacting negatively on the available habitat. This is also considered a health risk.

The water quality metric is the most impacted at 43.4%, followed by the habitat and flow modification metrics.

All taxa, except for >2spp. Baetidae, with a high requirement for unmodified physico-chemical conditions are absent, whilst taxa with a moderate requirement for unmodified physic-chemical conditions that do occur, generally occur at a lower abundance and frequency of occurrence than would be expected under natural conditions. The presence, abundance and frequency of occurrence of taxa that show preference for loose cobbles is highly impacted.

RIPARIAN VEGETATION

Marginal Zone

Reed and grass dominated state. This zone is steep in places with bank scouring visible; this may be due to the increased energy flows from the hardened surfaces of upstream urban and agricultural areas. The zone substrate consists mainly of soil. Good vegetation cover occurs in places, which is mainly dominated by exotic vegetation such as *Arundo donax, Melia azedarach, Salix babylonica, Populus x canescens*, etc. Some indigenous species include *Combretum erythrophyllum, Ziziphus mucronata, Celtis africana,* etc. A broken cement structure has contributed to bank scouring. Vigorous plant growth may have been intensified by bad water quality. This channel is part of a bigger floodplain system, with the adjacent wetland area contributing to the lateral inundation of the marginal zone.

Non-marginal Zone

This zone is dominated by trees and shrubs with reasonably good cover and abundance. Building rubble and old cement structures influence habitat availability. Many dead tree stumps are visible. This zone is steep to begin with, then levels out with a permanent wetland area adjacent to it. Trees and shrubs such as *Combretum erythrophyllum, Cliffortia linearifolia, Gymnosporia heterophylla, Diospyros lycioides,* etc. are present. Exotic vegetation consists mostly of *Arundo donax, Melia azedarach, Gleditsia triacanthos,* etc. The bank substrate is made up of soil, with wetland soils adjacent to it. There is an open water area in the wetland area with *Typha capensis*, *Eichhornia crassipes* and *Lemna gibba* dominating. Other wetland species include *Cyperus latifolia, Cyperus sexangularis, Eleocharis palustris*, etc.

The overall vegetation was in an E category, with a negative trend.

WATER QUALITY

No diatom sampling was conducted at this site.

7.3.2 IMPACTS, THREATS AND MANAGEMENT PRIORITIES IN THE APIES RIVER

The main impacts relating to the loss of ecological health include:

- Increased sedimentation, turbidity and enrichment resulting in poor water quality
- Habitat loss, due to algae growth and flow modification
- Invasion of alien fish species, (*Gambusia affinis* and CARP), which have a negative impact on the environment and native fish species and habitat (and other aquatic taxa)
- Invasion by exotic vegetation

Urgent management intervention is required to curb the rapid downward trend to an unsustainable condition of the Apies River. Some measures to be implemented include:

- Management of point-source discharges
- Management of land-use practices
- Ensure minimum ecological flow requirements
- Cooperation with environmental organisations to manage invasive alien species.

8 RESULTS IN THE LOWER CROCODILE SUB-AREA

This sub-management area represents the remainder of the Crocodile River catchment, downstream of the confluence with the Elands River (Figure 8-1). The river flows in a north/north-westerly direction until the confluence with the Marico River. After the confluence the river is known as the Limpopo River. The Lower Crocodile River has two large tributaries, namely the Sand River and the Bierspruit, which join the Crocodile River west of the town of Thabazimbi. Irrigation is the dominant water demand in this sub-area. Transfers to the Medupi Power Station in the Mokolo River catchment, is also taking place in the sub-catchment.

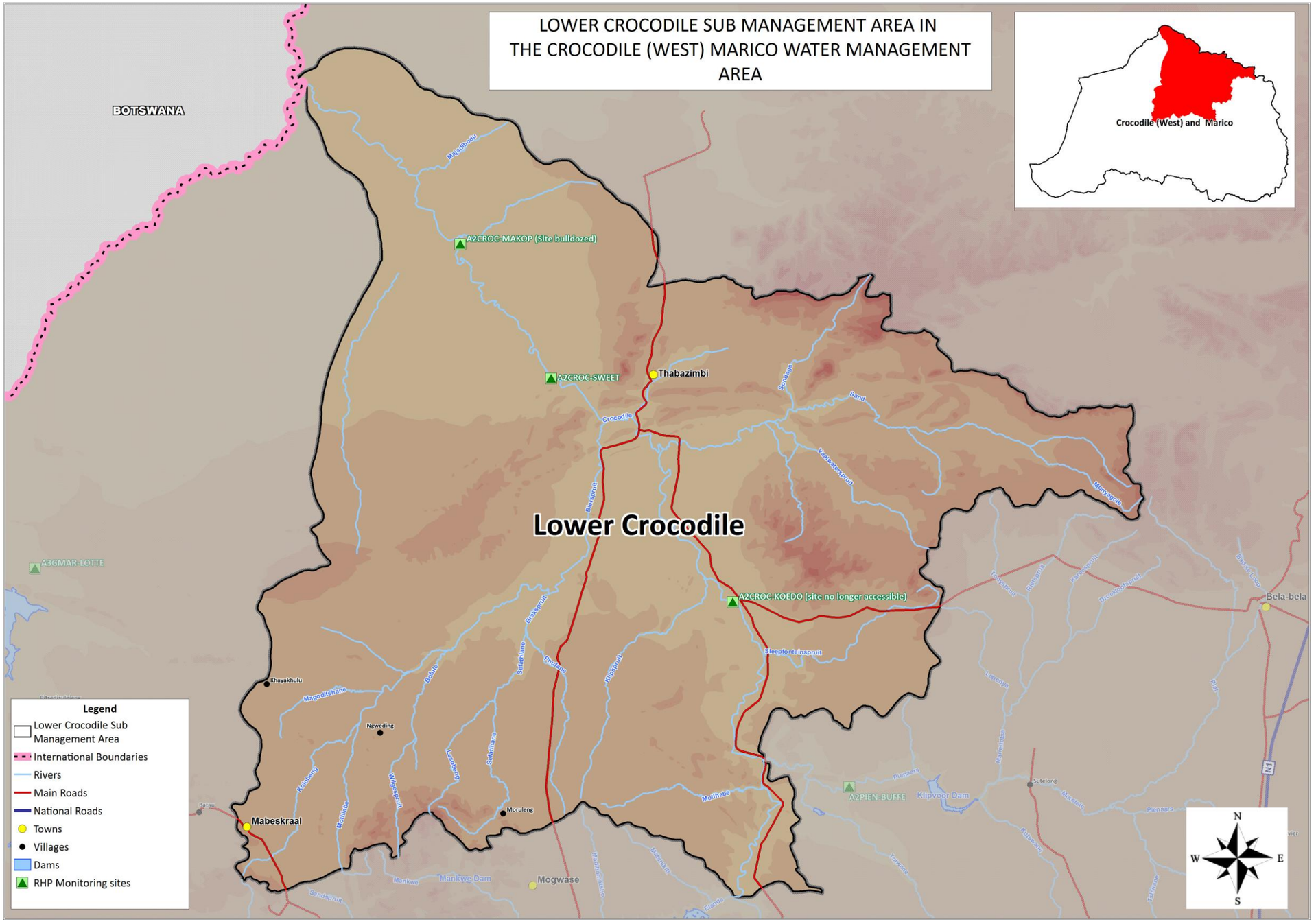


FIGURE 8-1. OVERVIEW OF THE LOWER CROCODILE RIVER SUB-AREA

8.1 RIVER HEALTH MONITORING SITES IN THE LOWER CROCODILE SUB-AREA

Two River Health Monitoring Sites were selected in the Lower Crocodile sub-area as provided in Table 8-1.

Site A2CROC-KOEDO, in SQ Reach A24C-00596, was not accessible and therefore not assessed during the study. An alternate site, A2CROC-SWEET was therefore sourced and assessed when possible. Site A2CROC-MAKOP, in SQ Reach A24J-00438 was bulldozed due to building activities at the weir immediately upstream of the site and was not suitable for river health monitoring during some of the monitoring events. A2CROC-SWEET, in the same reach as A2CROC-MAKOP was assessed during the study.

TABLE 8-1. SUB-QUATERNARY REACHES AND RIVER HEALTH MONITORING SITES IN THE LOWER CROCODILE SUB-AREA

MONITORING SITE	SQR REACH	RIVER NAME	SQR NUMBER	LATITUDE	LONGITUDE
	A24A-00760	Crocodile	C13.00		
	A24A-00749	Crocodile	C14.00		
	A24B-00669	Crocodile	C15.00		
A2CROC-KOEDO (site no longer accessible)	A24C-00596	Crocodile	C16.00	-24.88980	27.51833
	A24C-00536	Crocodile	C17.00		
	A24H-00516	Crocodile	C18.00		
	A24H-00510	Crocodile	C19.00		
A2CROC-MAKOP (Site bulldozed)	A24J-00438	Crocodile	C20.00	-24.40663	27.11545
A2CROC-SWEET				-24.5877	27.2497
	A24J-00413	Crocodile	C21.00		
	A24J-00324	Crocodile	C22.00		

8.2 ECOLOGICAL HEALTH OF THE LOWER CROCODILE RIVER

A large proportion of the Lower Crocodile River is in a poor ecological health, in a category D (refer to Figure 8-2) and improves slightly after inflows from the Sundays River.

Monitoring of reach A24J-00438, shows a decline in ecological condition over the 3 years, from a C category to a D category (Figure 8-3). This rapid decline in health is of concern and management intervention is required urgently to prevent further degradation to the ecological health of the river. Fish (Figure 8-4), riparian vegetation (Figure 8-7) and instream health (Figure 8-7) of the reach show the greatest declines in condition.

The assessment of the remaining reaches in the Lower Crocodile River were based on a desktop analysis of the Habitat Integrity, using Google Earth imagery. The assessment method was not sensitive enough to pick up deterioration within these reaches (Figure 8-3).

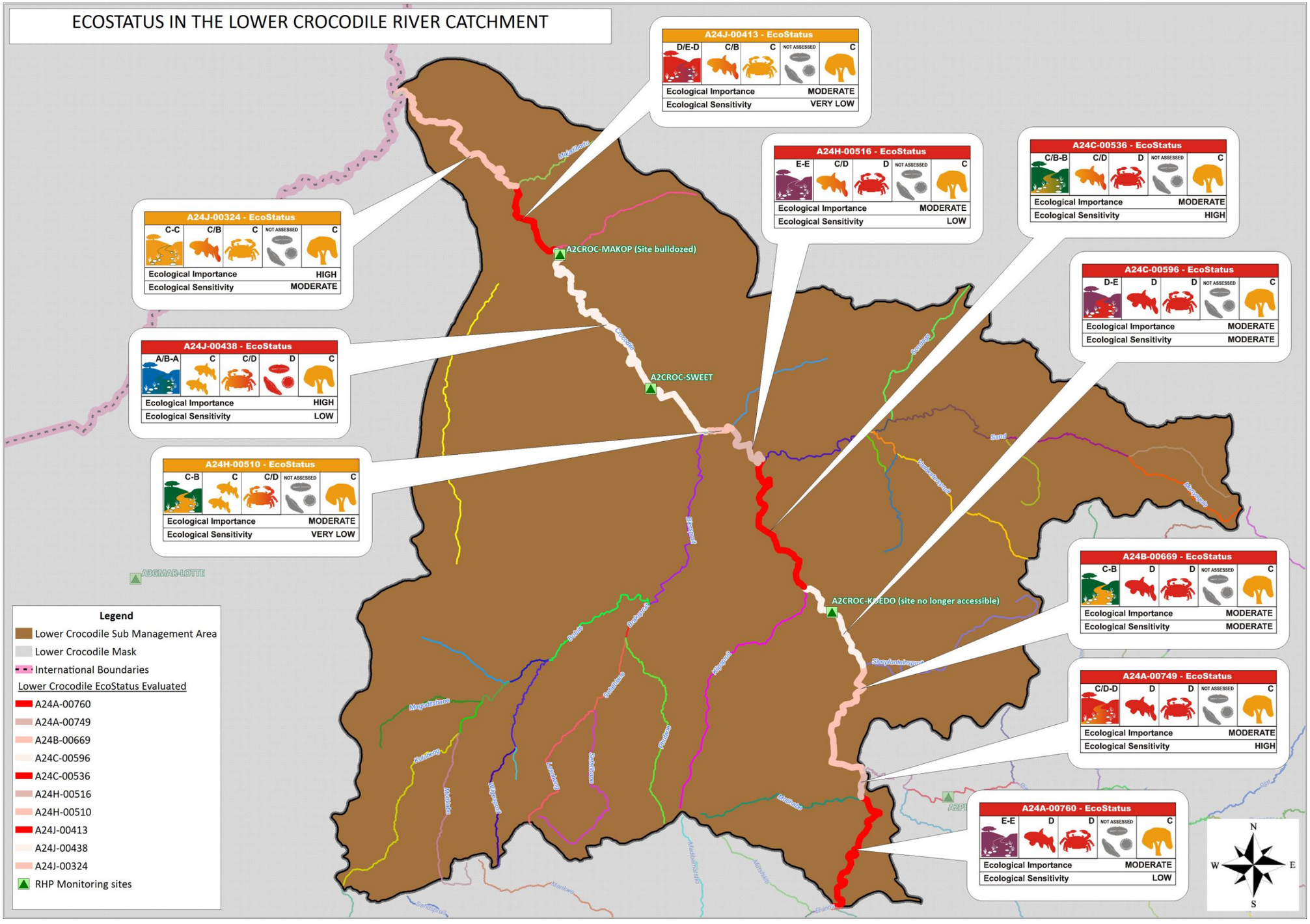


FIGURE 8-2. ECOLOGICAL STATUS OF THE LOWER CROCODILE RIVER

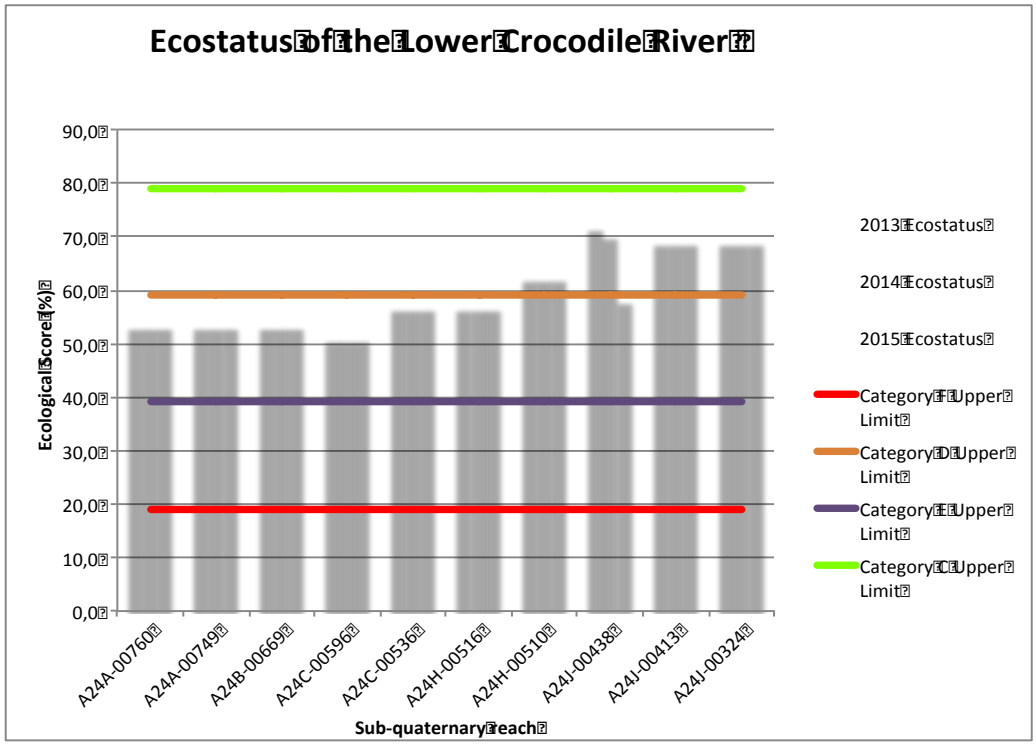


FIGURE 8-3. ECOSTATUS OF THE LOWER CROCODILE RIVER FROM UPSTREAM (LEFT) TO DOWNSTREAM (RIGHT)

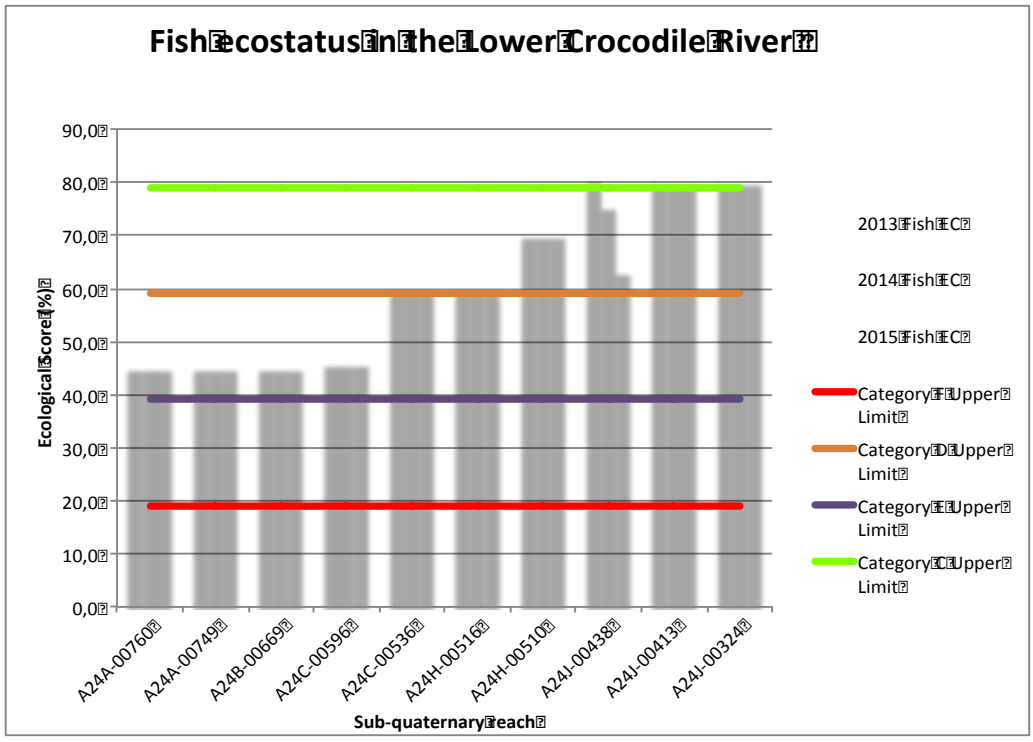


FIGURE 8-4. ECOLOGICAL STATE OF THE FISH IN THE LOWER CROCODILE RIVER

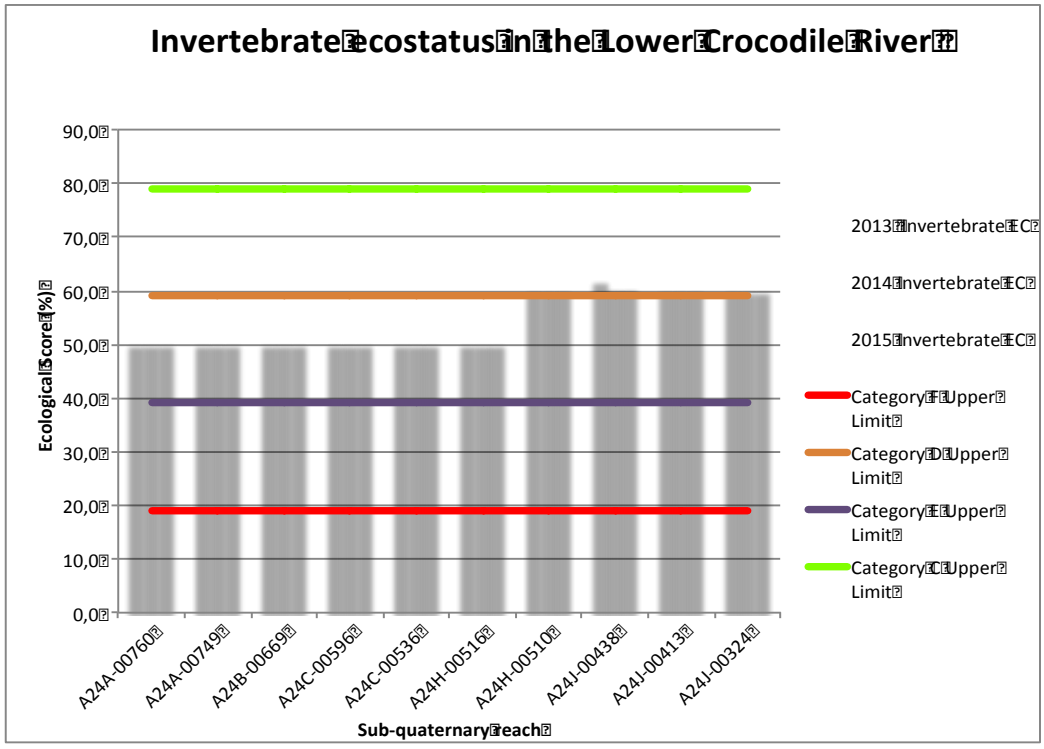


FIGURE 8-5. ECOLOGICAL STATE OF THE MACRO-INVERTEBRATES IN THE LOWER CROCODILE RIVER

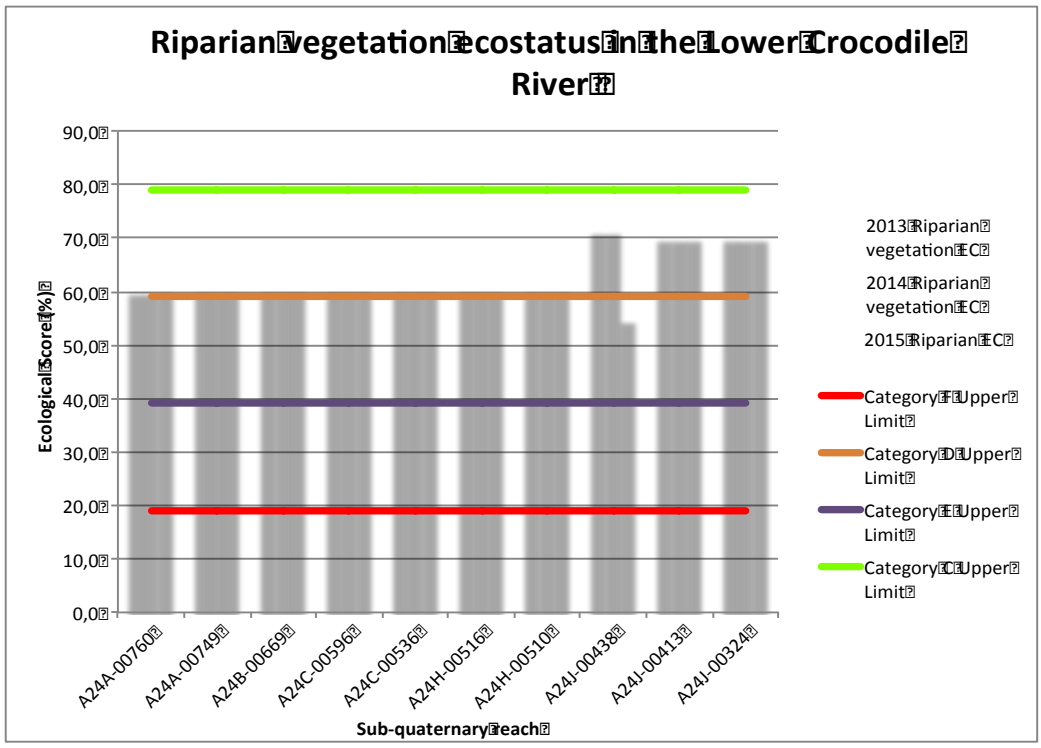


FIGURE 8-6. ECOLOGICAL STATE OF THE RIPARIAN VEGETATION IN THE LOWER CROCODILE RIVER

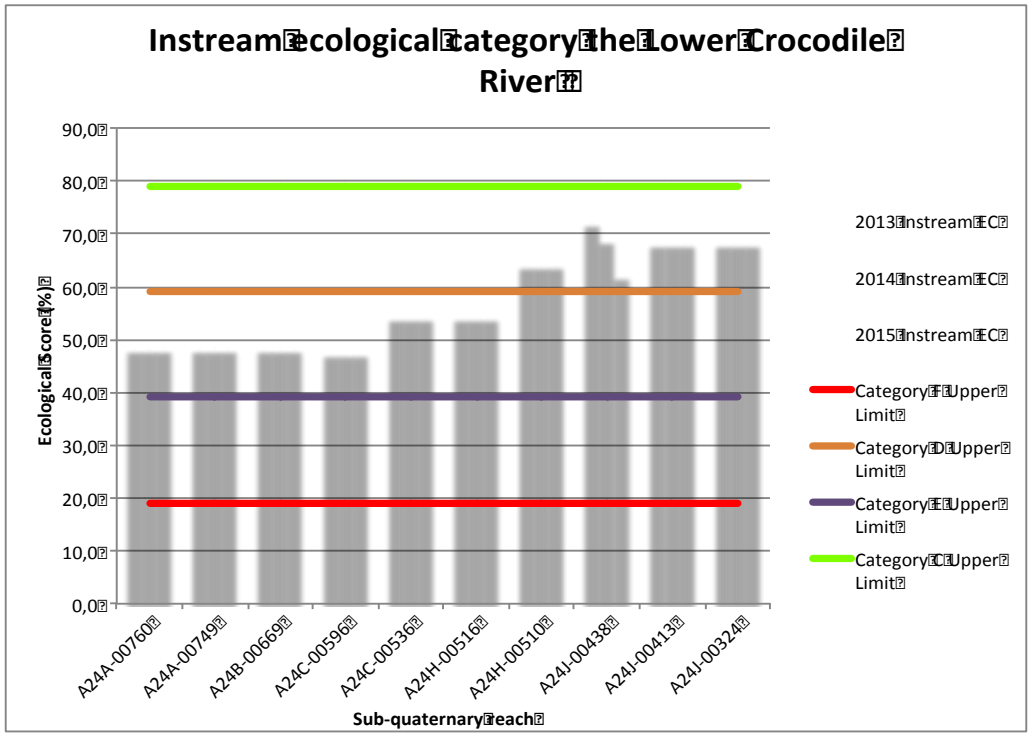


FIGURE 8-7. INSTREAM ECOLOGICAL HEALTH IN THE LOWER CROCODILE RIVER

8.2.1 MONITORING RESULTS: REACH A24J-00438 (REPRESENTED BY A2CROC-MAKOP AND A2CROC-SWEET

	
APRIL 2013	June 2014 (high flow)

	
Sept 2014	March 2015

FIGURE 8-8. A2CROC-MAKOP (REACH A24J-00438)

	
JUNE 2014 (very high flow)	SEPTEMBER 2014 (low flow)
	
March 2015 (Filamentous algal growth)	March 2015

FIGURE 8-9. A2CROC-SWEET (REACH A24J-00438)

GENERAL DESCRIPTION

This is the most downstream site on the Crocodile River for this project. This reach includes A2CROC-SWEET which is a regional RHP site situated further upstream in the reach, as well as site EWR8. A2CROC-MAKOP is situated immediately downstream of a weir as well as a bridge and is dominated by bedrock and stones instream habitat.

A2CROC-SWEET is situated at an old, low-water bridge that has been damaged. The site is located on the Crocodile River 16 km west of the town of Thabazimbi. Gabions and large, plastic bags filled with stones have been placed in the river to impede the flow for abstraction purposes. Sand has been bulldozed on top of the gabions to strengthen the makeshift dam wall. The site is severely impacted by these impediments and the riffle has been filled in with gabions and plastic bags.

FISH

A2CROC-MAKOP was surveyed for fish during April 2013, September 2014, and March 2015. During the other survey times (August 2013 – June 2014) the flow was too high for sampling, but visual surveys were conducted.

Deterioration in site habitat was observed from 2013 to 2014 to 2015 for both sites due to weir construction activities, loss of habitat and increased filamentous algal growth.

Since April 2013 the raising of the weirs at both sites has changed the variety of flow depth classes for habitat for fish, resulting in loss of habitat diversity at the sites.

Previously (2013) the fish habitat at A2CROC-MAKOP was adequate for all species expected, and most species expected were sampled during an April 2013 survey. The FRAI PES and EC were calculated at 80.4% and a B/C.

During the September 2014 survey both A2CROC-MAKOP and A2CROC-SWEET showed deterioration in site habitat quality and suitability for fish, either due to loss of flow depth classes from the two weir's alterations to fish habitat and due to increased enrichment of the water as observed from the abundant filamentous algae growth present at the sites. The FRAI PES and EC were calculated at 73% and a C.

During March 2015 both A2CROC-MAKOP and A2CROC-SWEET sites had a very low to no flow; any flow being present coming from water leaking/seeping through the weirs. During the March 2015 survey low flow was present at the site/s. Pool habitat is important for the site, and serves as refugia for fish, and large numbers of fish fry were recorded in mainly SS habitat. These sites received a reduced FROC for certain species with an affinity for fast flowing habitat. The PES and EC was derived from the species FROC and FRAI to be 63.1% C.

Exotic fish species such as *Gambusia affinis* and *Cyprinus carpio* will have a negative impact on the FROCs of native species.

MACROINVERTEBRATES

No sampling was possible at either of the sites in March 2015, due to no flow at A2CROC-MAKOP and A2CROC-SWEET being severely impacted due to new gabions and rocks being bulldozed on top of the old riffle and low-flow bridge, in order to dam the river for abstraction purposes. Thus no sampling was possible at either of these sites and the MIRAI remains the same as in 2014.

Eight data sets were used to run the MIRAI and derive an EC of C/D, using data for both A2CROC-MAKOP and A2CROC-SWEET. The most impaired metric is that of water quality, followed by instream habitat and flow. Taxa that have a high requirement for unmodified physico-chemical conditions and that are absent in the reach include Perlidae, Prosopistomatidae and Heptageniidae. Some of the taxa preferring fast flowing water, i.e. >0.6m/s include Tricorythidae, Simuliidae and >2spp. of Hydropsychidae were absent in this reach. The occurrence of taxa preferring cobbles and vegetation is impacted, whilst those taxa preferring bedrock and the GSM biotope are impacted to a lesser degree. Overall, the water quality driver seems to be contributing most to the impairment of the river in this reach, as is reflected in the absence of water quality sensitive taxa.

RIPARIAN VEGETATION

A2CROC-MAKOP

Marginal Zone

Grass (including some sedges) is the dominant state. *Cynodon dactylon* is the dominant grass species with other grasses such as *Paspalum distichum*, *Sorghum bicolor, Setaria verticillata*, and *Andropogon appendiculatus* also present. *Phragmites australis* and *Cyperus sexangularis* clumps occur. Bare patches occur in between, although bedrock is visible in places. The dominant substrate is sand. *Acacia gerrardii* is present, especially between the rocks. Impacts comprise weirs resulting in inundation and degradation downstream thereof, bank erosion, flooding, vegetation removal (mowing and grazing), exotic vegetation (mainly exotic pioneers in the marginal zone) and footpaths. Cover is good with reasonable abundance. It is suspected that, due to flooding, the exotic hydrophytic species *Eichhornia crassipes* has been washed away. The marginal zone is steep with bank undercutting taking place.

Non-marginal Zone

Tree and shrub dominated state. This zone is reasonably covered with vegetation. The non-woody component consists mainly of grass. The alien invader *Melia azedarach* and *Chenopodium album* occurs with other exotic pioneer vegetation such as *Melilotus albus, Datura stramonium* and *Xanthium strumarium*. A portion of the left bank downstream of the weir has been catastrophically changed due to the dumping of alluvial material and old building rubble. The woody species dominating include *Ziziphus mucronata, Acacia karroo, Acacia galpinii, Searsia lancea,* etc. Bank substrate consists of alluvial material (sandy). Bank scouring has taken place on the right bank due to the weir upstream of the site.

A2CROC-SWEET

Marginal Zone

Grass and reed (including some sedges) dominated state. *Cynodon dactylon* is the dominant grass species, with other grasses such as *Setaria verticillata* and *Andropogon appendiculatus* also present. *Phragmites australis* and *Cyperus sexangularis* clumps are present. The dominant substrate is soil and alluvial material, with sand included. Impacts comprise weirs and road crossings resulting in inundation and degradation downstream thereof, bank erosion, flooding, exotic vegetation (mainly exotic pioneers in the marginal zone) and the footprint of cultivation. It is suspected that, due to flooding, the exotic hydrophytic species *Eichhornia crassipes* has been washed away. The marginal zone is steep with bank undercutting taking place and concave with sand banks in places.

Non-marginal Zone

Tree dominated state. There is little shrub cover, with some grass and forb cover. The non-woody component consists mainly of grass and forbs. The alien invader *Melia azedarach* occurs with other exotic pioneer vegetation such as *Melilotus albus, Datura stramonium* and *Xanthium strumarium*. This zone consists of a lower and a higher bank. The higher bank is mostly dominated by trees. The woody species dominating include *Diospyros lycioides, Croton gratissimus, Ziziphus mucronata, Rhamnus zeyheri, Acacia karroo, Acacia galpinii, Acacia nigrescens, Searsia lancea*, etc. Bank substrate consists of alluvial material (soil and sand). Bank scouring has resulted in steep, eroded banks in places. There are indirect impacts from cultivation in the form of management roads, water pump stations, off-shore dams, etc

WATER QUALITY

No diatom sampling was conducted at this site.

8.2.2 IMPACTS, THREATS AND MANAGEMENT PRIORITIES IN THE LOWER CROCODILE RIVER

The main impacts relating in the loss of ecological health include:

- Impoundments affecting the natural flow regime
- Reduced water quality, due to eutrophication caused by agricultural return flows
- Abstraction for agriculture, which affects the natural flow regime
- Invasive aliens encroaching on the riparian zone
- Presence of carp naturally spreading and introduced for recreation / angling. Mosquito fish introduced from households (kept as aquarium fish), and introduced as mosquito control in certain areas in the past.

Management intervention is necessary to prevent further degradation of the river. Management priorities include:

- Control water use and manage water abstraction for agricultural purposes
- Ensure implementation and compliance to the Ecological Reserve requirements
- Monitor and control agricultural return flows
- Enforce compliance to water quality standards
- Rehabilitate the riparian habitat
- Clear the alien vegetation in the riparian zone and stabilise bank erosion
- Stricter control of introduction of alien fish species into the resource and manage the currently introduced alien species.

9 RESULTS IN THE MARICO SUB-AREA

The Marico sub-management area corresponds to the catchment of the Marico River. Main tributaries of the Marico River include the Klein and Groot Marico rivers (Figure 9-1). This sub-area forms the western part of the WMA. Major dams in this sub-catchment are the Marico-Bosveld Dam in the upper catchment and the Molatedi Dam further downstream. The town of Zeerust is found in this sub-management area with smaller settlements scattered throughout. The Groot Marico River is fed by a number of springs within the Groot Marico dolomitic aquifer compartment. These dolomitic eyes include the Molemane Eye and the Marico Eye. The upper reaches of this catchment are not densely populated.

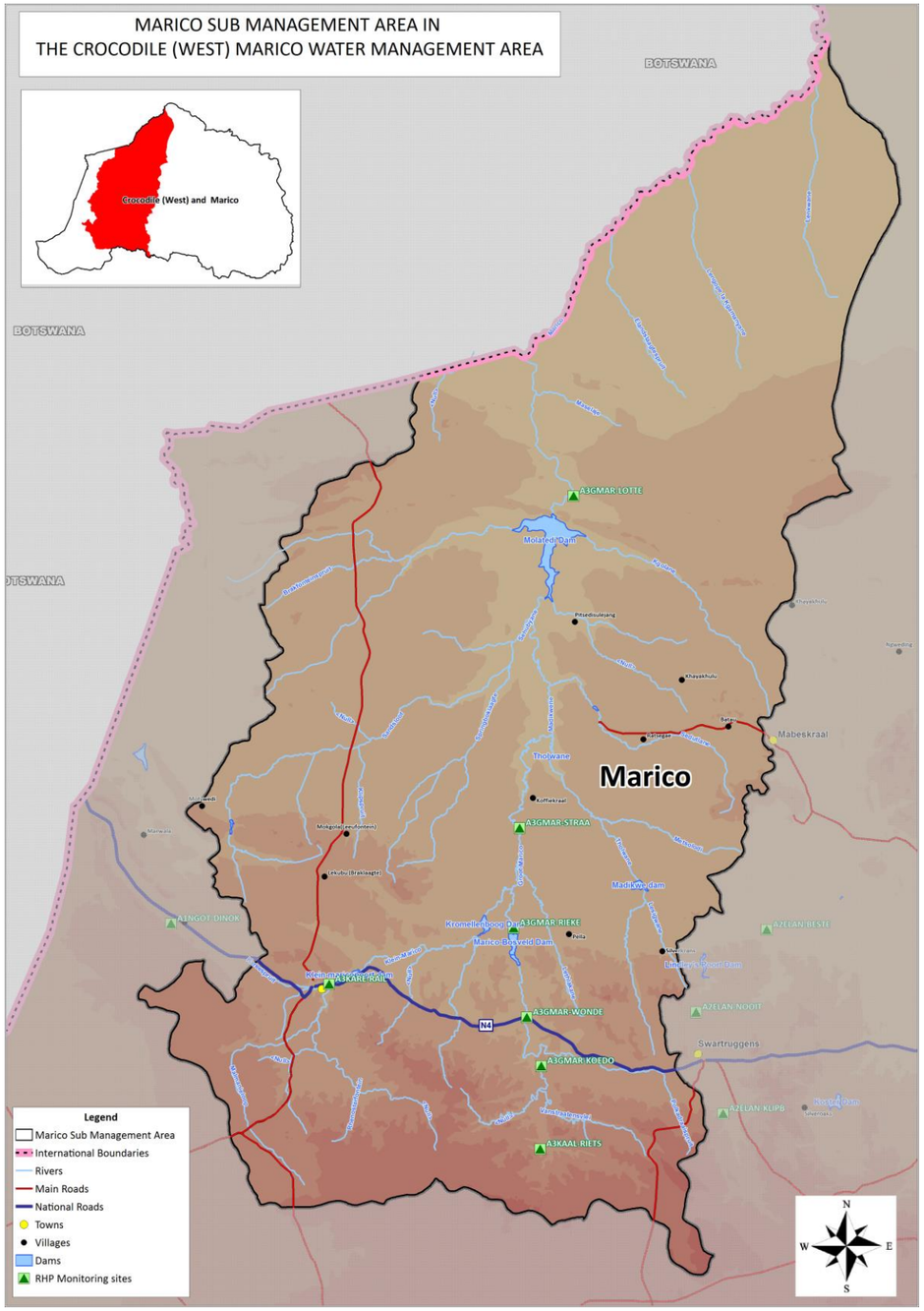


FIGURE 9-1. OVERVIEW OF THE MARICO SUB-MANAGEMENT AREA

9.1 RIVER HEALTH MONITORING SITES IN THE MARICO SUB-AREA

Six monitoring sites were selected in the Marico sub-area. These sites are representative of the reaches in which they are located. Table 9-1 provides the sub-quaternary reaches within the Marico Sub-Area and the River Health Monitoring Sites that have been sampled over the project period.

TABLE 9-1. SUB-QUATERNARY REACHES AND RIVER HEALTH MONITORING SITES IN THE MARICO SUB-AREA

MONITORING SITE	SQR REACH	RIVER NAME	SQR NUMBER	LATITUDE	LONGITUDE
	A31A-0800	marico (Ribbokfontein se Loop)	GM01.00		
A3KAAL-RIETS	A31A-0400	Kaaloog se Loop	GM01.01	-25.77700	26.43339
	A31A-0900	marico (Ribbokfontein se Loop)	GM02.00		
A3GMAR-KOEDO	A31B-01039	Groot-Marico	GM03.00	-25.65870	26.43500
A3GMAR-RIEKE	A31B-00923/Groot-Marico B	Groot-Marico	GM04B.00	-25.46120	26.39189
A3GMAR-WONDE	A31B-00923/Groot-Marico A	Groot-Marico	GM04A.00	-25.58903	26.41253
	A31F-00907	Groot-Marico	GM05.00		
A3GMAR-STRAA*	A31F-00768	Groot-Marico	GM06.00	-25.31861	26.40100
	A31G-00742	Madikwene	GM07.00		
	A31G-00687	Madikwene	GM08.00		
	A32A-00662	Marico	GM09.00		
	A32A-00621	Marico	GM10.00		
A3GMAR-LOTTE	A32D-00539	Marico	GM12.00	-24.84439	26.48600
	A32D-00514	Marico	GM13.00		
	A32E-00430/Marico	Marico	GM15.00		
	A32E-00337/Marico	Marico	GM16.00		
	A31D-00967	Kareespruit	KM04.01		
A3KARE-RAIL	A31D-00968	Kareespruit	KM04.03	-25.54147	26.10222
A3KARE-ABJAT^				-25.54147	26.10222

*TERTIARY SITE

^RAW SEWAGE IN RIVER NO INSTREAM BIOTA SAMPLED

9.2 ECOLOGICAL HEALTH OF THE MARICO RIVER

The overall ecological state of the Marico River system is in a Fair condition, placing it in a moderately modified ecological category C (refer to Figure 9-2). The Kareespruit, a tributary of the Marico is currently in a D category (refer to Figure 9-3 and Figure 9-3).

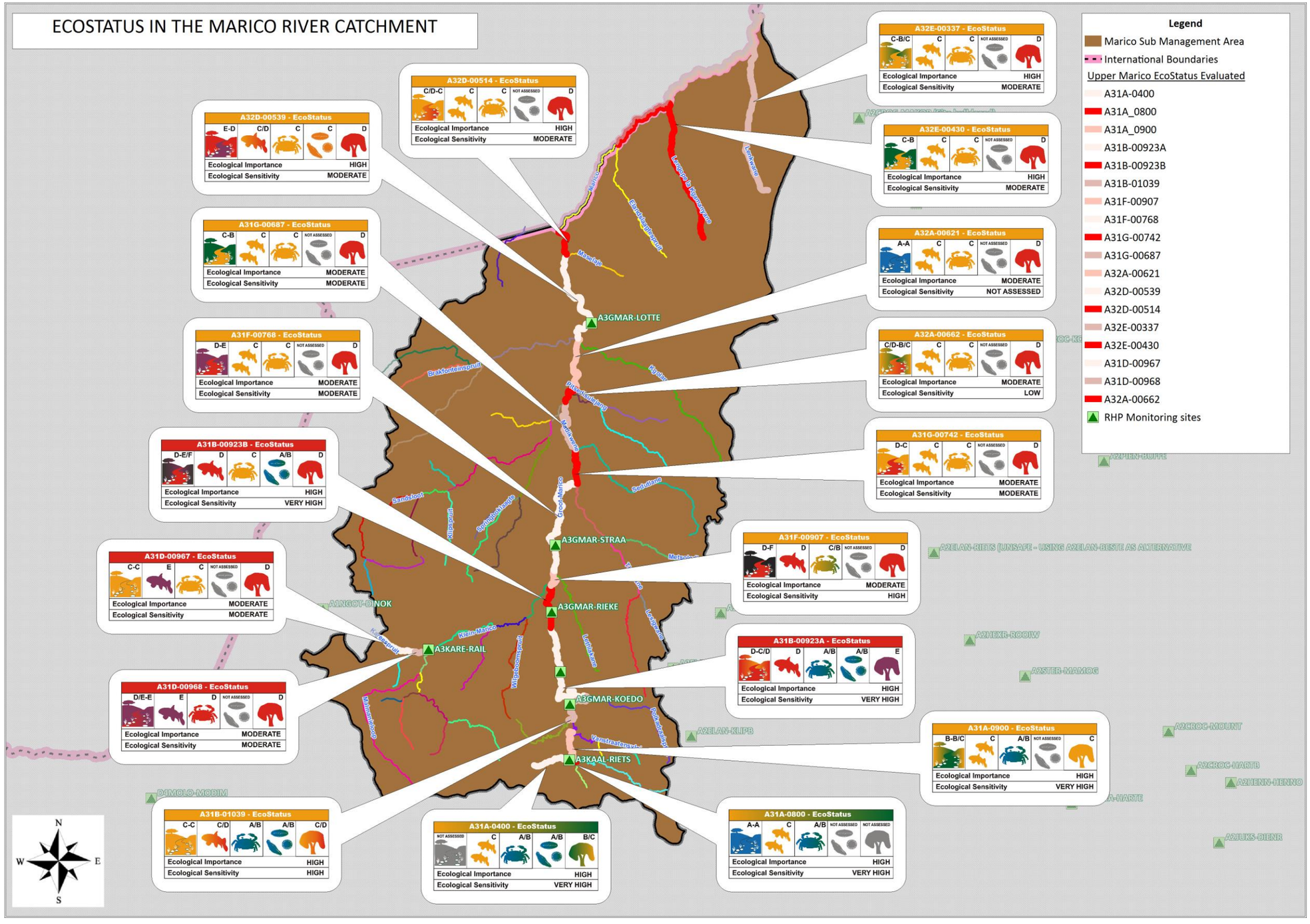


FIGURE 9-2. ECOLOGICAL STATE OF THE MARICO RIVER CATCHMENT

Monitoring over the 3-year period has shown a decline in ecological health score of the fish (Figure 9-4), riparian vegetation (Figure 9-6) and macro-invertebrates (Figure 9-5), although remaining in a constant ecological category. The instream Ecostatus and macro-invertebrate health is very good, in an A condition.

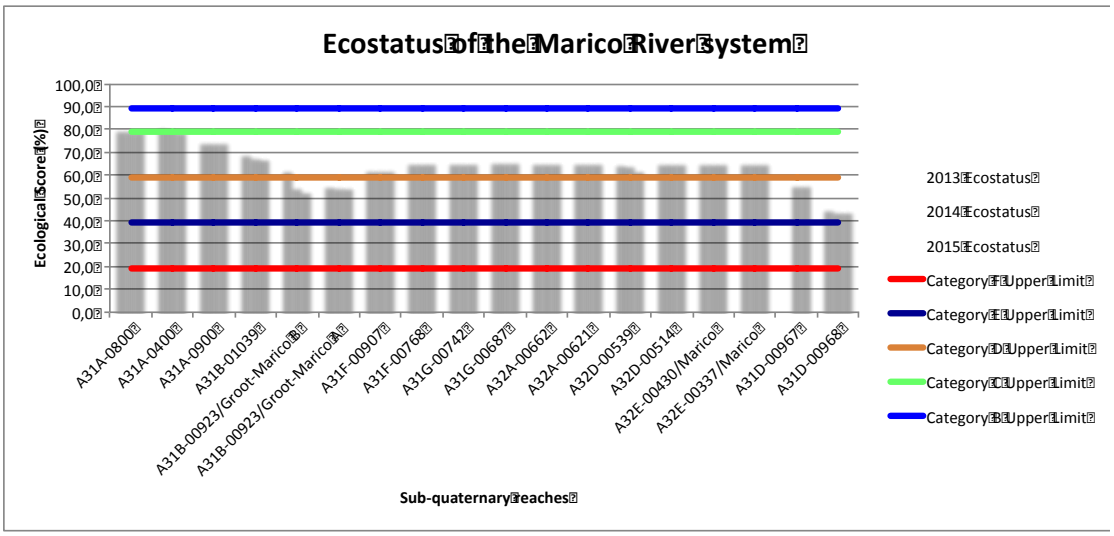


FIGURE 9-3. ECOSTATUS OF THE MARICO RIVER CATCHMENT FROM UPSTREAM TO DOWNSTREAM (LAST TWO POINTS, A31D-00967 AND A31D-00968 ARE ON THE KAREESPRUIT)

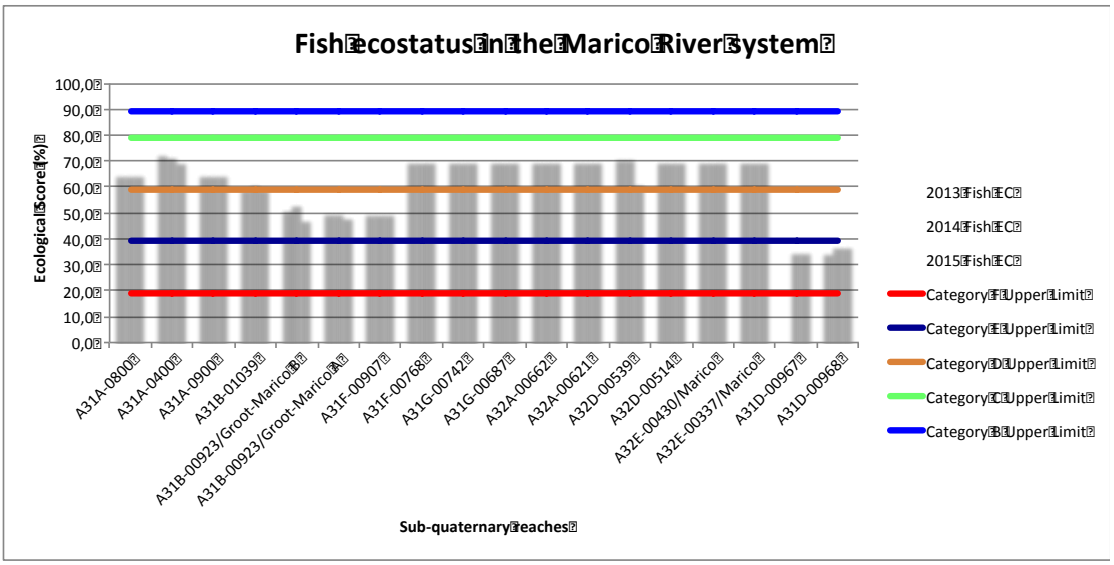


FIGURE 9-4. ECOLOGICAL STATE OF FISH IN THE MARICO CATCHMENT

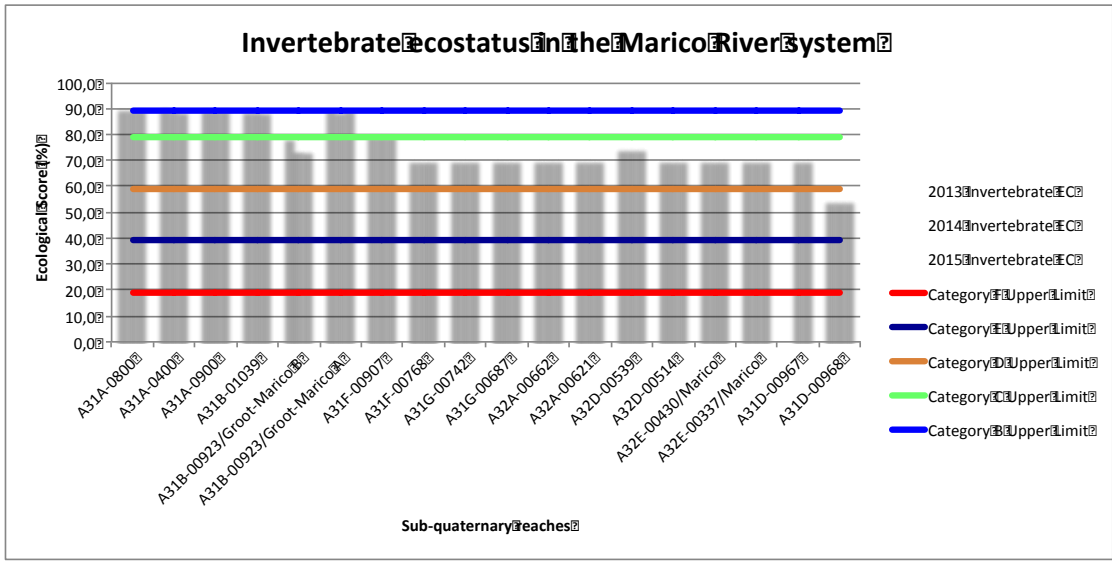


FIGURE 9-5. ECOLOGICAL STATE OF THE MACRO-INVERTEBRATES IN THE MARICO RIVER CATCHMENT

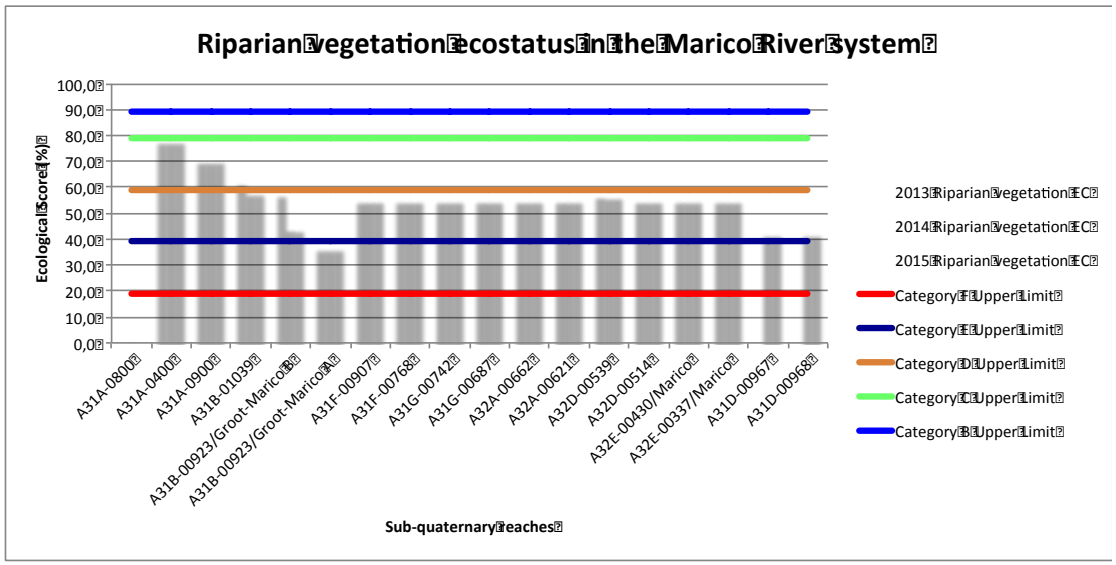


FIGURE 9-6. ECOLOGICAL STATE OF THE RIPARIAN VEGETATION IN THE MARICO RIVER CATCHMENT

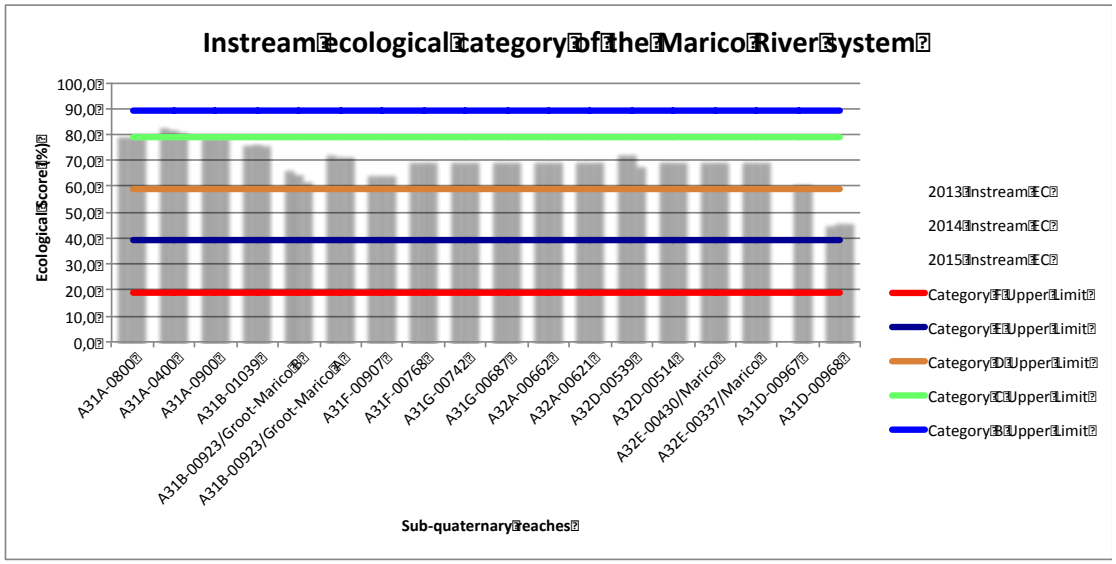


FIGURE 9-7. INSTREAM ECOLOGICAL HEALTH IN THE MARICO RIVER CATCHMENT

9.2.1 MONITORING RESULTS: REACH A31A-0400 (REPRESENTED BY A3KAAL-RIETS)

AUGUST 2013

SEPTEMBER 2014

MARCH 2015

MARCH 2015

FIGURE 9-8. A3KAAL-RIETS (A31A-0400)

GENERAL DESCRIPTION

This site is situated on the Kaaloogseloop, downstream of a dolomitic eye, which forms the source of the system. The reach is mostly natural, except for abstraction from the dolomitic aquifer, some dry land farming in the upper section of the reach, as well as slate mining in the reach.

FISH

This site was surveyed during April and August 2013, June and September 2014, and March 2015. The site seems to have stayed in a constant EC (ranging from 72.8 C to 72 / C to 70 / C from 2013-2014-2015) with little variations in fish species sampled. The flow was dominated by the fast shallow (FS) velocity depth class during 2015 and the FROCs of species with a high preference for SS (slow shallow) and FD (fast deep) were reduced resulting in a slightly lower EC for March 2015.

The water was clear with low algal growth during all surveys.

All the expected fish species are expected to still be present within this SQ Reach although the Frequency of Occurrence (FROC) of some species has been reduced slightly from reference conditions. One additional species were sampled – *Chiloglanis paratus*.

Reduced FROC's were given mostly for species with a preference for SD and FD habitats, as these habitats are mostly absent or sparse.

Species with a preference for substrate (rocks and rocky habitat etc.) such as *Chiloglanis paratus*, *Chiloglanis pretoriae, Amphilius uranoscopus, Labeo cylindricus* and *Labeo molybdinus* etc. also received reduced FROC's, as there is some siltation/sedimentation and algae growth present at the site. Enrichment will also play a role in the abundance and occurrence of species. Enrichment may be a problem, and this also influenced the FROC's of species which are moderately intolerant to WQ modification (these also/again include *Chiloglanis paratus*, *Chiloglanis pretoriae, Amphilius uranoscopus, Labeo cylindricus*, as well as *Labeo molybdinus*).

Most fish were sampled in low numbers.

MACROINVERTEBRATES

Twenty one data sets were used to run the MIRAI to derive an EC of A/B, with data extending from 2005 to 2015. The water quality metric is minimally impacted at 86.7%, followed by the flow modification and habitat metrics.

All taxa with a high requirement for unmodified physico-chemical conditions are present, except for Prosopistomatidae, whilst those with a moderate requirement for unmodified physic-chemical conditions are also all present except for Lepidostomatidae. Most of the taxa generally occur at the expected abundance and frequency of occurrence, except for example, Perlidae which occurs at an A abundance instead of the expected B abundance. The presence, abundance and frequency of occurrence of taxa with all flow and habitat preferences are minimally impacted, if at all for some of the modification metrics.

Changes in the taxa from 2014 to 2015 are minimal and include changes to the abundance and/or frequency of occurrence of taxa with a preference for loose cobbles, as well as to those with a low requirement for modified physico-chemical conditions.

RIPARIAN VEGETATION

Marginal Zone

Sedge and grass dominated state. Sedges occur in clumps, such as *Schoenoplectus brachyceras, Cyperus longus,* etc. Some tree and shrub juveniles occur (*Celtis africana*, *Combretum erythrophyllum, Acacia gerrardii, Buddleja salviifolia,* etc.). Vegetation cover is good, apart from the few erosion sites and footpath crossings. The left bank is steep with bedrock due to a rock face. Grazing and trampling signs are visible. Substrate consists of mostly rocks and pebbles. Some scouring and bank slumping is present. Zone is dominated by *Eragrostis megaphylla*, *Setaria incrassata, Plantago longissima, Berula erecta,* etc. Woody cover and abundance is good in relation to the reference condition. Water quality is eutrophic of nature and this could be due to mining activities upstream.

Non-marginal Zone

Zone consists of two terraces, one higher than the other (RIGHT BANK). High flow channels are present. This zone is in a tree dominated state with some shrubs; species that include *Searsia lanceolata, Gymnosporia senegalensis, Olea europaea*, *Acacia karroo, Diospyros whyteana,* etc. Steep zone on LEFT BANK. This zone has good vegetation cover and abundance. Grass component is poorly represented and includes species such as *Setaria megaphylla, Setaria incrassata, Paspalum urvillei*, etc. There is an increase in alien invader species (*Acacia dealbata*). Good tree and shrub cover has resulted in less undergrowth, although lots of *Hibiscus calyphyllus* is present. Upper terrace looks like an old road clearing. Substrate consists of soil and loose rocks. Grazing and trampling have resulted in less grass cover and signs of erosion are visible.

The overall vegetation remains in a stable B/C category.

WATER QUALITY

The site is in an Ecological Category A (High quality). The species assemblages recorded are characterised by prevalent *Encyonopsis leei var. sinensis* and *Achnanthidium minutissimum*, taxa found in well oxygenated, oligo- to mesotrophic waters with low to moderate electrolyte content. There is also presence of sub-dominant taxon *Cocconeis placentula var. placentula* which suggests minor nutrient enrichment. Hence the category for the site can be lowered to an A/B (High quality).

9.2.2 MONITORING RESULTS: REACH A31B-01039 (REPRESENTED BY A3GMAR-KOEDO)

	
APRIL 2013	SEPTEMBER 2014

	
MARCH 2015	MARCH 2015

FIGURE 9-9. A3GMAR-KOEDO (A31B-01039)

GENERAL DESCRIPTION

This site is situated on the Groot Marico River, downstream of a road bridge. The land use in this reach includes dry land and some irrigated farming practises. Weirs are also present, as well as some exotic vegetation e.g. Poplar trees and exotic fauna, i.e. bass. Water is abstracted for domestic and agricultural use.

FISH

This site was surveyed during April and August 2013, June and September 2014, and March 2015. The site seems to have stayed in a constant EC with small variations in EC in fish species sampled during the surveys.

The water was relatively clear at the site during 2014, but with increased filamentous algae growth during the 2014 surveys. The filamentous algae growth was low to moderate in areas. Less filamentous algae was observed during March 2015.

During March 2015 the flow (velocity depth classes) was dominated by fast shallow and the fish with a high preference for this flow received increased FROCs. Fish species with a high affinity for SS and SD received reduced FROCs.

All the expected fish species are expected to still be present within this SQ Reach although the Frequency of Occurrence (FROC) of some species has been reduced slightly from reference conditions. One additional species was sampled – *Micropterus salmoides* which is an alien predator with a negative impact on the native species diversity and densities. There is predation by bass in SD habitat (deep water column), but also in other habitats. There will be a negative trend for the PES due to the presence of bass. Nutrient enrichment also seems to be problematic and of importance at this site.

MACROINVERTEBRATES

Fifteen data sets were used to run the MIRAI to derive an EC of A/B, with data from 2005 to 2015. The water quality metric is minimally impacted at 87.0%, followed by the flow modification and habitat metrics.

Almost no change has been observed in the MIRAI for this SQR during the 2013/2014/2015 period and this site, as it pertains to macroinvertebrate communities and their survival (due to the potential impacts), is considered stable.

All taxa with a high requirement for unmodified physico-chemical conditions are present, except for Pyralidae, whilst those with a moderate requirement for unmodified physico-chemical conditions are also all present except for Lepidostomatidae. Most of the taxa generally occur at the expected abundance and frequency of occurrence, except for example, Elmidae, Psephenidae and Aeshnidae which occur at a slightly decreased abundance than expected. The presence, abundance and frequency of occurrence of taxa with all flow and habitat preferences are minimally impacted, if at all for some of the modification metrics.

RIPARIAN VEGETATION

Marginal Zone

Grass and sedge dominated state, with species such as *Cyperus compressus, Cyperus sexangularis, Schoenoplectus brachyceras, Diheteropogon amplectens, Phragmites australis,* etc. In some places scouring occurs in the form of undercutting into the rocky bank, exposing the root mass of shrubs and trees. Shrubs and trees do provide shady conditions. The dominant woody species are *Buddleja salviifolia, Salix mucronata,* etc. The vegetation is scattered here and there. There is poor species diversity. The substrate consists of rocky, pebble material (conglomerate). Exotic vegetation consists mainly of pioneers in the form of *Persicaria decipiens, Verbena bonariensis, Pseudognaphalium luteo-album*, etc.

Non-marginal Zone

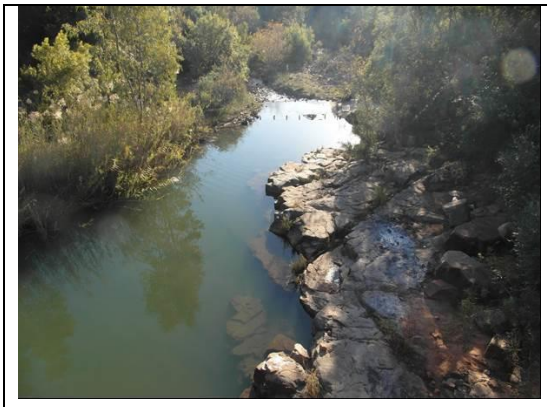
Tree and shrub dominated state. There is poor under-cover vegetation. Substrate is rocky with boulders and areas of bedrock providing little habitat availability, especially on the LEFT BANK. Good vegetation cover occurs where habitat is available on both sides. There is poor species diversity. Dominant species are *Searsia lanceolata, Celtis africana, Gymnosporia senegalensis, Acacia galpinii, Ziziphus mucronata*, *Olea europaea*, etc. Exotic vegetation such as *Morus alba*, *Arundo donax, Melia azedarach, Salix babylonica, Populus x canescens*, etc. is extensive, especially on the right bank. There are signs of terrestrialization, with species such as *Dombeya rotundifolia*, *Dichrostachys cinerea*, etc. Flood damage visible in the form of dead tree stumps lying around and broken vegetation (especially that of exotic vegetation).

The overall vegetation is in a C/D ecological state with a negative trend.

WATER QUALITY

A3GMAR-KOEDO is in an Ecological Category A (High quality). The species assemblages recorded are characterised by prevalent *Encyonopsis leei var. sinensis* and *Achnanthidium minutissimum*, taxa found in well oxygenated, oligo- to mesotrophic waters with low to moderate electrolyte content. The presence of sub-dominant taxon *Cocconeis placentula var. placentula* suggests minor nutrient enrichment. Hence the category mentioned above can be lowered to an A/B (High quality).

9.2.3 MONITORING RESULTS: REACH A31B-00923/GROOT MARICO B (REPRESENTED BY A3GMAR-RIEKE)



JUNE 2014

SEPTEMBER 2014

MARCH 2015

MARCH 2015

FIGURE 9-10. A3GMAR-RIEKE (A31B-00923/GROOT MARICO B)

GENERAL DESCRIPTION

This site is situated on the Groot Marico River, immediately downstream of the Marico Bosveld Dam and downstream of a weir. The land use in this reach includes dry land and irrigated farming practises. Weirs are also present, as well as exotic vegetation and exotic fauna, i.e. bass. Water is abstracted for domestic and agricultural use

FISH

The site was sampled during April 2013, June and September 2014, and during March 2015. It was visually surveyed during August 2013. Site conditions basically remained the same from 2013 to 2014 to 2015. Lower flow was, however, present during March 2015 compared to previous years and the EC and PES were reduced during March 2015 but remains in a D category (53.57% D for 2013-2014, and 47.6% D for 2015). The EC was reduced due to the FROCs of species with a high affinity for FS and FD habitat being reduced as FS habitat was less abundant and FD habitat absent.

All the expected fish species are expected to still be present within this SQ Reach although the Frequency of Occurrence (FROC) of some species has been reduced slightly from reference conditions.

Species with a preference for substrate (rocks and rocky habitat etc.) also received reduced FROC's, as there is some siltation/sedimentation and algae growth present at the site. Enrichment may be a problem at the site, and this also influenced the FROC's of species which are intolerant to moderately intolerant to WQ modification (*Chiloglanis pretoriae, Labeo cylindricus, Labeo molybdinus, Amphilius uranoscopus*, and *Barbus motebensis*).

The presence of largemouth bass negatively impacts on native fish species in the area.

Large dams, weirs, and water abstraction (flow modification) leading to low water levels and fewer events for flushing sediments will result in habitat deterioration and species loss. Dams and weirs and low water levels also influence species migration negatively.

MACROINVERTEBRATES

Twelve data sets were used to run the MIRAI to derive an EC of C, with data extending from 2005 to 2015. The water quality metric is the most impacted at 70.7%, followed by the flow modification and habitat metrics.

Minimal changes were observed between 2014 and 2015, with frequency of occurrence and/or abundance of taxa showing a preference for very fast flowing water showing some change between 2014 and 2015.

All taxa with a high requirement for unmodified physico-chemical conditions are present, except for Pyralidae and Helodidae, and those present generally show a decreased frequency of occurrence than what would be expected under natural conditions. Most of the taxa with a moderate requirement for unmodified physico-chemical conditions are present, with some showing a decrease in abundance and expected frequency of occurrence. The abundance and frequency of occurrence of taxa showing a preference for loose cobbles is fairly impacted.

RIPARIAN VEGETATION

Marginal Zone

Open dominated state with roots of trees (*Searsia lancea, Combretum erythrophyllum*) being exposed. Scattered sedges and grasses (*Cyperus sexangularis, Bothriochloa insculpta, Cynodon dactylon, Phragmites australis,* etc.) are present. Vegetation cover is poor, little habitat available. *Equisetum ramosissimum* is dominating the non-woody component. Substrate consists of alluvial material in the form of rocks and pebbles. Little to no top soil available for vegetation growth. Human activities in the form of footpaths exist (culturally important for religious purposes). Bank armouring takes place due to the dam and road crossing upstream of the site. Zone is dominated by exotic pioneers (*Verbena officinalis, Tagetes minutes, Ricinus communis*, etc.).

Non-marginal Zone

This zone is dominated by trees and shrubs. A high flow channel occurs on the right bank, which is sparsely covered with grass and forbs (*Melinis repens, Setaria megaphylla*, *Sansevieria aethiopica* and lots of *Equisetum ramosissimum*). This zone has good tree cover in the upper-zone. Indigenous trees dominating are *Olea europaea* and *Seersia lancea*. Lots of exotic vegetation is present, mainly in the form of pioneers (Hibiscus *calyphyllus, Persicaria officinalis, Tagetes minutes, Pseudognaphalium luteo-album*) and trees *Salix babylonica,*

Eucalyptus grandis. The upper bank substrate consists of soil, with a high flow channel that is scattered with rocks and pebbles. Other impacts such as footpaths (mainly from humans), erosion due to high flows and armouring exist.

The overall vegetation is in a D category with a negative trend.

WATER QUALITY

Based on the OMNIDIA results, the ecological water quality at Site A3GMAR-RIEKE is of a category A (High quality) with a negligible amount of organic content in the system (0.3 %PTV). This is reflected by the presence of prevalent taxon *Achnanthidium minutissima*, which is generally indicative of clean, well oxygenated, freshwaters. Recorded at the site are dominant *Encyonopsis leei var. sinensis* and *Cymbella kappii*, taxa affiliated with oligo- to mesotrophic waters with low to moderate electrolyte content. The presence of dominant taxon *Fragilaria capucina var. capucina* commonly associated with good quality waters e.g. waters from a dolomitic eye with naturally elevated salinity and pH, has also been found in industrial and mine impacted waters. Sub-dominant taxa *Aulacoseira granulata var. angustissima* and *Fragilaria biceps* points to minor organic and inorganic nutrient inputs. The water quality at Site A3GMAR-RIEKE can be assigned a more appropriate ecological category A/B (High quality) given the fact that there are slight nutrient inputs in the system.

9.2.4 MONITORING RESULTS: REACH A31B-00923/GROOT MARICO A (REPRESENTED BY A3GMAR-WONDE)

APRIL 2013 | JUNE 2014

SEPT 2014 | MARCH 2015

FIGURE 9-11. A3GMAR-WONDER (A31B-00923/GROOT MARICO A

GENERAL DESCRIPTION

This site is situated on the Groot Marico River, at the N4 bridge, downstream of Groot Marico town. The land use in this reach includes dry land and some irrigated farming practises. The Marico Bosveld Dam is situated in the lower section of this reach. Weirs are also present, as well as exotic vegetation and exotic fauna, i.e. bass. Water is abstracted for domestic and agricultural use.

FISH

The site was surveyed during April and August 2014, June and September 2014, and during March 2015. No major changes in the fish assembly were observed between 2013, 2014 and 2015. Sewage spills are, however, of concern in this reach and the trend for the PES will remain negative (due to increased enrichment/eutrophication), if this problem is not resolved.

Lower flow was observed during March 2015 and combined with enrichment some species received lower FROCs. The PES EC varied from 50.1% D for 2013-2014 to 48.4% D during March 2015.

All the expected fish species are expected to still be present within this SQ Reach although the Frequency of Occurrence (FROC) of some species has been reduced from reference conditions.

The presence of largemouth bass will negatively impact on native fish species in the area and will contribute to the negative PES trend.

Large dams, weirs, and water abstraction (flow modification) leading to low water levels and fewer events for flushing sediments will result in habitat deterioration and species loss. Dams and weirs and low water levels also influence species migration negatively.

MACROINVERTEBRATES

Twenty five data sets were used to run the MIRAI to derive an EC, with data extending from 2005 to 2015. The water quality metric is minimally impacted at 87.6%, followed by the habitat and flow modification metrics.

Minimal change has been observed overall in the SQR from 2013 to 2015.

All taxa with a high requirement for unmodified physico-chemical conditions are present, as well as those with a moderate requirement for unmodified physic-chemical conditions. Most of the taxa generally occur at the expected abundance and frequency of occurrence, except for example, Elmidae, Aeshnidae, Atyidae and Philopotamidae which occur at a slightly decreased abundance than expected. The presence, abundance and frequency of occurrence of taxa with all flow and habitat preferences are minimally impacted, if at all for some of the modification metrics.

RIPARIAN VEGETATION

Marginal Zone

Herb and reed dominated state. Vegetation extends into shallow water in places. Species in the area include *Juncus dregeanus, Cyperus sexangularis, Pycreus pelophilus, Kyllinga alata, Phragmites australis*, *Gomphostigma virgatum*, etc. Deep scouring (bank collapse) is taking place on the right bank, with bank scouring also occurring lower down on the left bank. Clumps of grasses and sedges are scattered within this

disturbed environment. Substrate consists of deposited building rubble, rock and soil. Human activities in the form of dumping and footpaths are visible. Many exotic pioneers and trees are present (*Salix babylonica, Verbena bonariensis, Tagetes minutes, Ricinus communis, Tithonia rotundifolia, Arundo donax*, etc.).

Non-marginal Zone

Tree and reed dominated state. Steep slope due to bank collapse on the right bank at beginning of study site as well as lower down on left bank. Cultivation extends into riparian zone on downstream section. Both banks have poor cover and abundance of trees and shrubs. Reeds dominate this zone lower down the system. The following species occur: *Dodonaea angustifolia*, *Searsia lancea, Olea europaea, Combretum erythrophyllum, Celtis africana*, etc. Banks are infested with exotic vegetation *Arundo donax, Melia azedarach, Tithonia rotundifolium*, *Salix babylonica, Morus alba*, *Eucalyptus grandis*, etc. Bank substrate consists of building waste, alluvium deposits and soil material.

The overall vegetation is in a E category, with a negative trajectory of trend.

WATER QUALITY

The site is in an Ecological Category A (High quality). The species assemblages recorded at the site is characterised by prevalent *Encyonopsis leei var. sinensis* and *Achnanthidium minutissimum*, taxa found in well oxygenated, oligo- to mesotrophic waters with low to moderate electrolyte content. The slight presence of taxa indicative of alkaline waters with elevated electrolytes (*Navicula reichardtiana, Navicula microcari, Navicula zanoni*) may point to minor disturbance of the system. Hence the categories for this site can be lowered to an A/B (High quality).

9.2.5 MONITORING RESULTS: REACH A32D-00539 (REPRESENTED BY A3GMAR-LOTTE)

	
APRIL 2013	JUNE 2014

SEPTEMBER 2014

MARCH 2015

FIGURE 9-12. A3GMAR-LOTTE (A32D-00539)

GENERAL DESCRIPTION

This site is situated on the Groot Marico River, approximately 6 kilometres downstream of Molatedi Dam. The land use in this reach includes some dry land farming and resorts. Weirs are also present in the reach. Water is abstracted for domestic and some agricultural use.

FISH

The site was surveyed during April 2013 and June 2014. It was visually assessed during August 2013 and September 2014. The site was again surveyed during March 2015.

SS (slow shallow) pools dominated the site during March 2015. With continued no flow conditions and the pools gradually becoming drier, a negative impact on the FROCs of species with a high affinity for FS and FD is observed.

The EC was reduced from a 71% C for 2013-2014 to a 61 C/D during March 2015 due to constant no flow conditions and increased strain put on species with a high affinity for fast flowing conditions.

MACROINVERTEBRATES

Six data sets were used to run the MIRAI to derive an EC of C, with data extending from 2005 to 2011. The water quality metric is the most impacted at 67.0%, followed by the flow modification and habitat metrics.

All taxa with a high requirement for unmodified physico-chemical conditions are absent, except for >2spp Hydropsychidae, which occurs at a lower than expected frequency of occurrence. Taxa with a moderate requirement for unmodified physic-chemical conditions that are absent include Chlorocyphidae, Psephenidae and Hydraenidae, with those that are present mostly occur at a decreased frequency of occurrence. The presence, abundance and frequency of occurrence of taxa showing a preference for loose cobbles is fairly impacted.

MIRAI was not re-run during 2014 because no additional SASS data was available due to low to no flow in June and September 2014.

The EC remains the same in 2015 because no further data was available in 2015, as no sampling was possible in March 2015, due to low flow conditions

RIPARIAN VEGETATION

Marginal Zone

The vegetation is dominated by grasses and sedges. The right bank has short grass and clumps of sedges; the mud bars have stands of *Typha capensis, Schoenoplectus brachyceras* and *Phragmites australis*. Indications are that there is an increase in mud, which can smother riparian habitat. Signs of trampling and grazing are evident. Scattered trees and shrubs are present. The left bank is scoured, with the roots of trees and shrubs being exposed. Overhanging trees give shade over the marginal zone. The zone's substrate consists of alluvial soil material and mud. Human activities in the form of footpaths exist. Exotic pioneers are present (*Verbena officinalis, Tagetes minuta, Ricinus communis*, etc.).

Non-marginal Zone

Mostly tree dominated state. Tree removal (wood cutting) takes place on the right bank. A high flow terrace occurs on the left bank. Trees do provide good cover on the left bank. Species such as *Acacia gerrardii, Combretum erythrophyllum, Searsia lancea, Searsia pyroides, Celtis africana*, etc. dominate this zone. Little to no shrubs occur, with only forbs growing on the ground. The dominant forb is *Teucrium trifidum*. The exotic climber *Macfadyena anguish-cati* is common in the non-marginal zone on the left bank. Upper bank substrate consists of alluvial soil material. Impacts occur in the form of cattle tracks with signs of overgrazing and trampling, erosion, wood cutting, short grass cover for recreation on the right bank, exotic vegetation (*Salix babylonica, Melia azedarach,* etc.).

The overall vegetation is in a stable D category.

WATER QUALITY

A3GMAR-LOTTE has been assigned an Ecological Category C (Moderate quality). The site has a high abundance of *Navicula cryptotenella*, a taxon which has been associated with agricultural impacts. The site shows signs of some industrial disturbances due to the presence of *Fragilaria capucina var. capucina, Fragilaria capucina var.vaucheriae* and *Fragilaria fasciculata,* taxa often associated with industrial effluent. Recorded at the site are dominant taxa *Cyclotella ocellata, Cymbella turgidula* and *Navicula reichardtiana* found in meso-eutrophic, calcareous waters (optimum pH 8.4) with moderately electrolyte rich content. For reasons mentioned above, the Ecological Category for Site A3GMAR-LOTTE can remain a category C (Moderate quality).

9.2.6 MONITORING RESULTS: REACH A31D-00968 (REPRESENTED BY A3KARE-RAILW)

APRIL 2013

JUNE 2014

SEPTEMBER 2014

MARCH 2015

FIGURE 9-13. A3KARE-RAILW (A31D-00968)

GENERAL DESCRIPTION

This site is situated on the Kareespruit downstream of the town of Zeerust. Potential impacts in this reach include runoff from Zeerust, return-flows from the wastewater treatment works, run-off from a golf course, impacts from light industry, bulldozing of sections of the river channel.

FISH

Visual surveys were conducted during April and August 2013, June and September 2014, and March 2015. Poor conditions remain present for this site and the EC still remains in an E (37.2). The site is difficult to sample and poses a health risk due to upstream pollution and sewage input.

All the expected fish species are expected to still be present within this SQ Reach although the Frequency of Occurrence (FROC) of some species has been reduced from reference conditions.

Species with a preference for substrate (rocks and rocky habitat etc.) received reduced FROC's, as there is siltation/sedimentation and algae growth present at the site (BMAR). Enrichment will also play a role in the abundance and occurrence of all the other species.

Road run-off and water pollution from Zeerust, the wastewater treatment works and surrounding mines will also negatively influence the FROC's of species intolerant and moderately intolerant to water quality modification.

Large dams, weirs, and water abstraction (flow modification) leading to low water levels and fewer events for flushing sediments will result in habitat deterioration and species loss. Dams, weirs and low water levels also influence species migration negatively.

Flow modification, in this case low flows, results in poor habitat quality, poor water quality, loss of habitat integrity, and possible loss of species.

MACROINVERTEBRATES

The MIRAI was not re-run for 2014 because no further SASS data was available due to high flows and sewage present during June and September 2014 respectively. No sampling was conducted in 2015 due to sewage present in the system. This is considered a health risk.

Fifteen data sets were used to run the MIRAI to derive an EC OF D, with data extending from 2005 to 2013. The water quality metric is the most impacted at 33.2%, followed by the flow modification and habitat metrics.

All taxa with a high requirement for unmodified physico-chemical conditions are absent. Taxa with a moderate requirement for unmodified physico-chemical conditions that are absent Leptophlebiidae, Elmidae, Tricorythidae and Psephenidae. Those taxa that are present mostly occur at a decreased frequency of occurrence and abundance. The presence of taxa with a preference for fast flowing water is largely impacted. The presence of taxa showing a preference for loose cobbles is largely impacted.

RIPARIAN VEGETATION

Marginal Zone

Grass and reed dominated state. Vegetation extends into shallow water in places, with the following species being dominant: *Typha capensis, Schoenoplectus brachyceras, Imperata cylindrica,* etc. Erosion takes place on the left bank, exposing the roots of trees and resulting in bank collapse. On this site there is good grass and sedge cover, although species consist mostly of exotics. Indications are that the reach is more impacted by erosion, infrastructural footprints such as golf course, road crossings, etc. The substrate consists of deposited soil. Human activities in the form of dumping and footpaths are visible. Many exotic species are present (*Pennisetum clandestinum*, *Arundo donax, Verbena officinalis, Tagetes minutes, Ricinus communis, Tithonia multiflora*, etc.).

Non-marginal Zone

Tree and reed dominated state. The bank on the left is steep, with the right bank being more flattish. The footprint of previous town development extends into riparian zone, with old building waste impacting on available habitat. Reasonable cover and abundance of trees occurs on the left bank, with species such as *Searsia lancea, Ziziphus mucronata, Celtis africana,* etc. being present. The grasses *Imperata cylindrica* and *Pennisetum clandestinum* are abundant. This riparian area is also infested with exotic vegetation: *Arundo*

donax, Populus x canescens, Melia azedarach, Sesbania punicea, Lantana camara, etc. *Ipomoea purpurea* is a climber covering large portions of the vegetation. Bank substrate consists of old building rubble, alluvium and soil material. Raw sewage spills take place into the riparian zone

The overall vegetation is in a D/E category with a negative trajectory of change.

WATER QUALITY

Diatom analysis was not conducted at this site.

9.2.7 IMPACTS, THREATS AND MANAGEMENT PRIORITIES IN THE MARICO RIVER CATCHMENT

The **Upper Marico River catchment (A31)** is in a Good to Fair condition. The condition deteriorates below the Marico Bosveld Dam, but then improves again after the confluence with the Klein Marico.

Drivers of change in this Upper system include:

- Impoundments and flow regulating structures affecting the natural flow regime
- Reduced water quality, due to eutrophication caused by agricultural return flows and uncontrolled WWTW.
- Abstraction for agriculture, which affects the natural flow regime, by reducing the low flows required for aquatic biota and for creating suitable habitat conditions.
- Invasive aliens encroaching on the riparian zone.
- Sedimentation from shale mining activities in the Highveld and agriculture
- Increased flow velocity, due to runoff and increased point source discharges, resulting in bank erosion
- Alien fish (Bass) affecting the native species

Management intervention will be required to:

- Control water use and manage water abstraction for agricultural purposes
- Ensure implementation and compliance to the Ecological Reserve requirements
- Monitor and control agricultural return flows
- Enforce compliance to water quality standards
- Enforce compliance to discharge standards
- Rehabilitate the riparian habitat
- Consider installing fish ladders and eelways in suitable flow regulating structures

- Clear the alien vegetation in the riparian zone and stabilise bank erosion
- Control alien fish
- Identify and control sources of urban runoff that impacts water quality and habitat integrity.

The **Lower Marico catchment** is in a FAIR condition.

Drivers of change in this Lower system include:

- Impoundments and flow regulating structures affecting the natural flow regime
- Water demand exceeding supply
- Reduced water quality, due to eutrophication caused by agricultural return flows
- Abstraction for agriculture, which affects the natural flow regime
- Sedimentation due to agriculture
- Overgrazing

Management intervention will be required to:

- Control water use and manage water abstraction for agricultural purposes
- Ensure implementation and compliance to the Ecological Reserve requirements
- Investigate dam releases that simulate natural flow patterns
- Monitor and control agricultural return flows
- Enforce compliance to water quality standards
- Rehabilitate the riparian habitat
- Stabilise bank erosion and establish erosion rehabilitation programmes
- Control overgrazing

10 RESULTS IN THE NGOTWANE SUB-MANAGEMENT AREA

The Ngotwane River catchment is a small catchment in the west of the Water Management Area. The Ngotwane River is a shared watercourse running along the border with Botswana. Refer to Figure 10-1. The rivers in the catchment are ephemeral, experiencing mostly brief seasonal flow depending on the rainfall. They do experience flash floods.

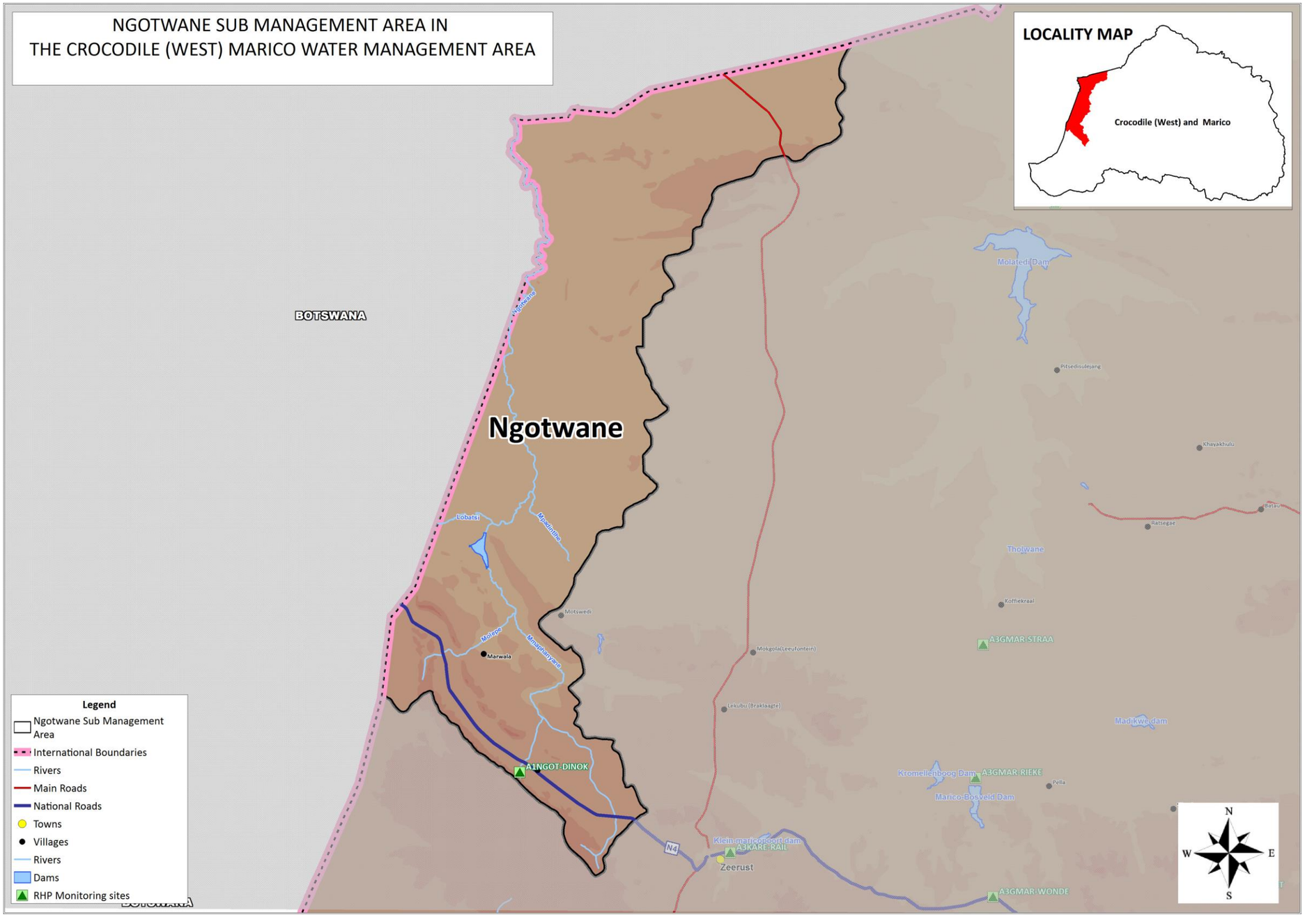


FIGURE 10-1. OVERVIEW OF THE NGOTWANE SUB-MANAGEMENT AREA

10.1 RIVER HEALTH MONITORING SITES IN THE NGOTWANE SUB-MANAGEMENT AREA

One monitoring site was selected in the Ngotwane Sub-Management Area. This site is representative of the reach in which it is located. Table 10-1 provides the sub-quaternary reaches within the Ngotwane sub-area and the River Health Monitoring Site that has been sampled over the project period.

TABLE 10-1. SUB-QUATERNARY REACHES AND RIVER HEALTH MONITORING SITE IN THE NGOTWANE SUB-AREA

MONITORING SITE	SQR REACH	RIVER NAME	SQR NUMBER	LATITUDE	LONGITUDE
A1NGOT-DINOK	A10A-00915	Ngotwane	NG01.00	25.853444°	25.455636°
	A10A-00985		NG01.01		
	A10A-00971		NG01.02		
	A10A-00914		NG01.03		
	A10A-00839		NG02.00		
	A10A-00838		NG02.01		
	A10A-00785		NG03.00		
	A10B-00735		NG03.01		
	A10B-00764		NG04.00		
	A10B-00765		NG04.01		
	A10B-00641	Ngotwane	NG05.00		
	A10B-00000	Ngotwane	NG06.00		

10.2 ECOLOGICAL HEALTH OF THE NGOTWANE RIVER

The health of the upper reaches of the Ngotwane River catchment is in a C category (Figure 10-2). Although it remained in the same ecological category, the health of the reach did deteriorate during 2014-2015 (Figure 10-3). The riparian vegetation showed the most change in ecological condition since 2013 (Figure 10-6). The instream health (Figure 10-7), fish (Figure 10-4) and macro-invertebrates (Figure 10-5) do not show much change in ecological condition over the three-years of monitoring.

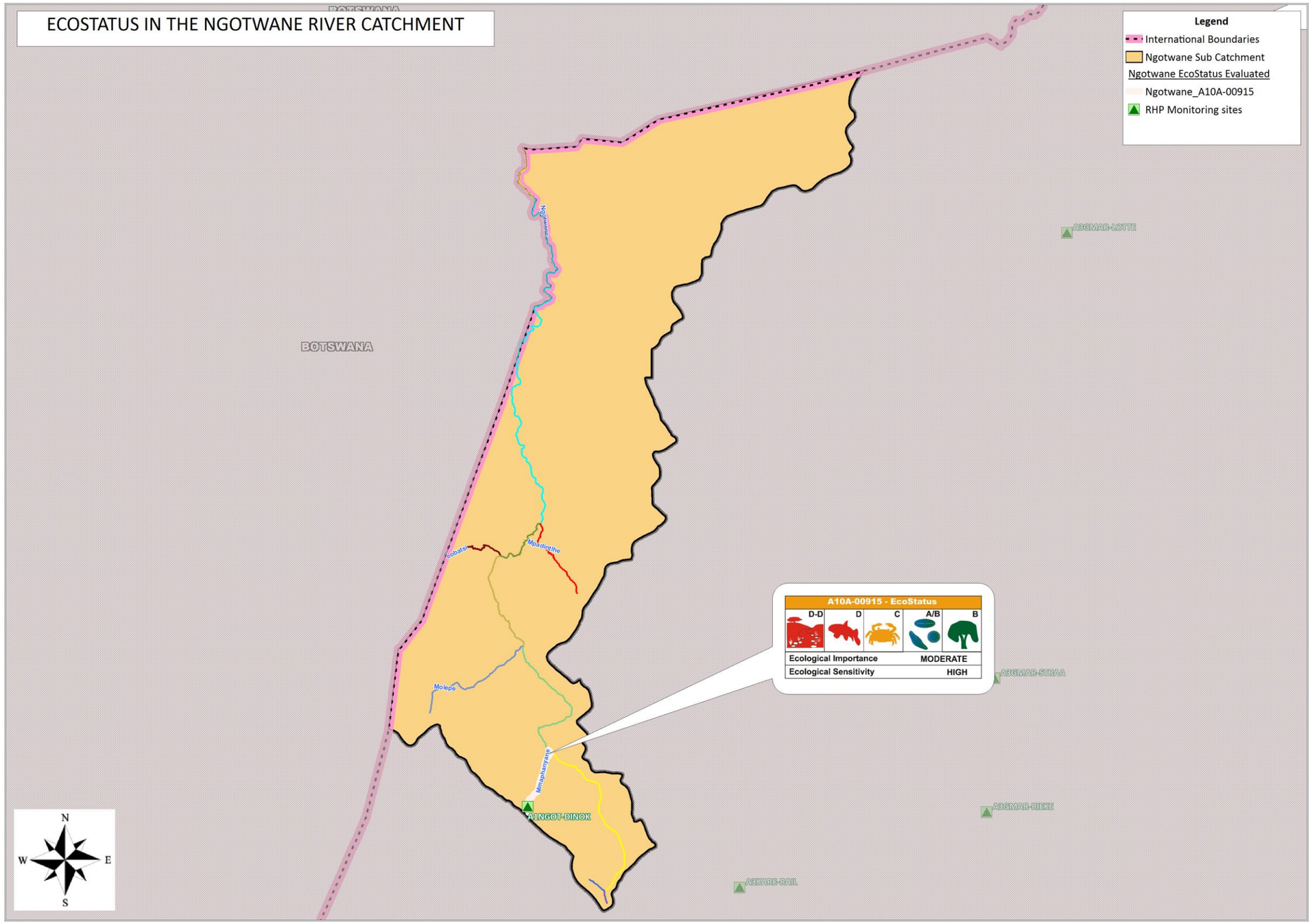


FIGURE 10-2. ECOLOGICAL STATE OF THE NGOTWANE RIVER

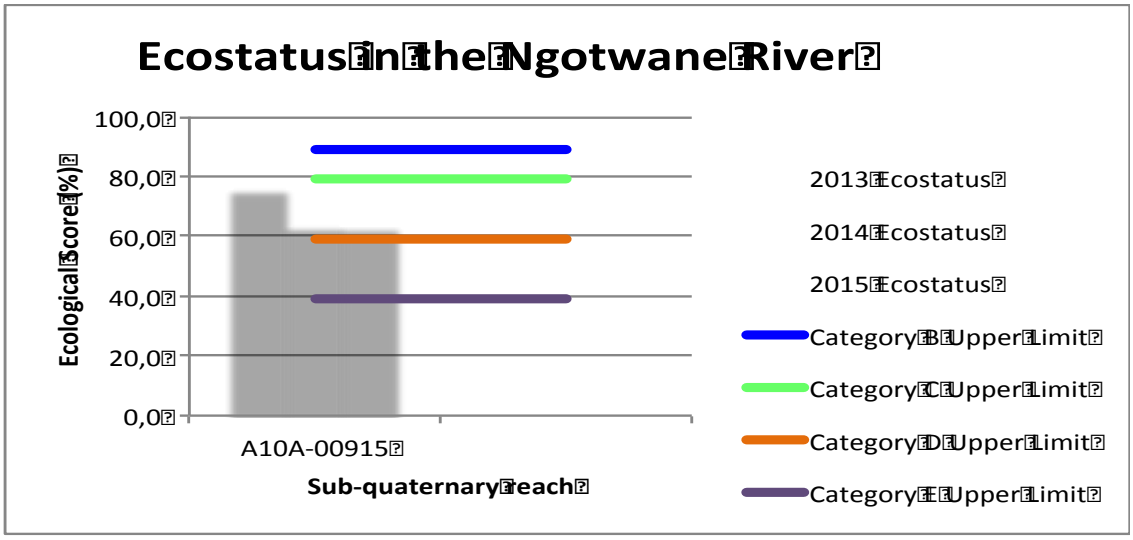


FIGURE 10-3. ECOSTATUS OF THE NGOTWANE RIVER (UPPER REACHES)

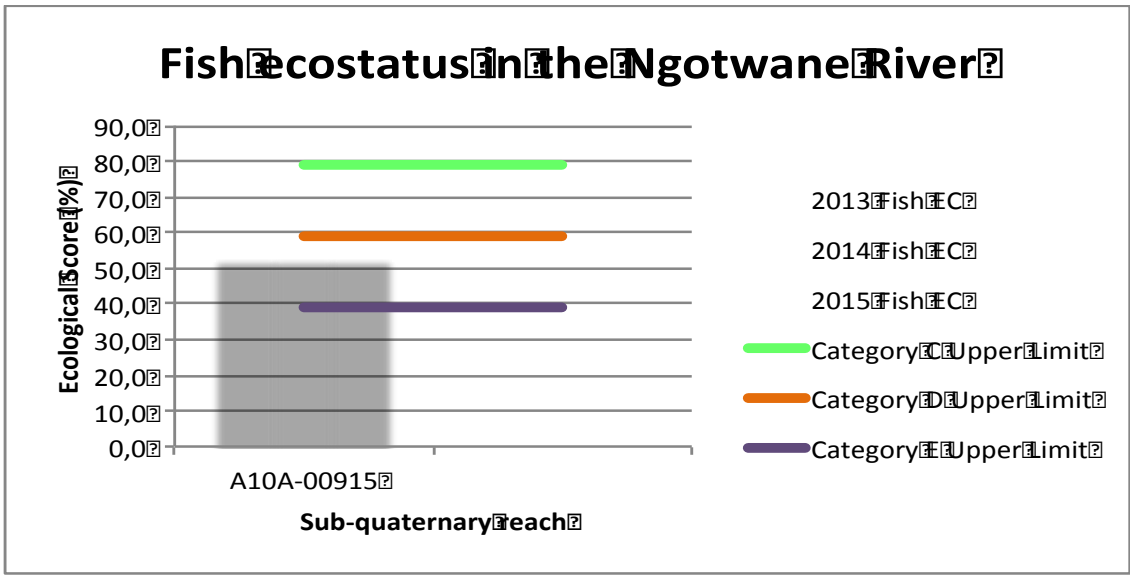


FIGURE 10-4. ECOLOGICAL STATE OF THE FISH IN THE NGOTWANE RIVER

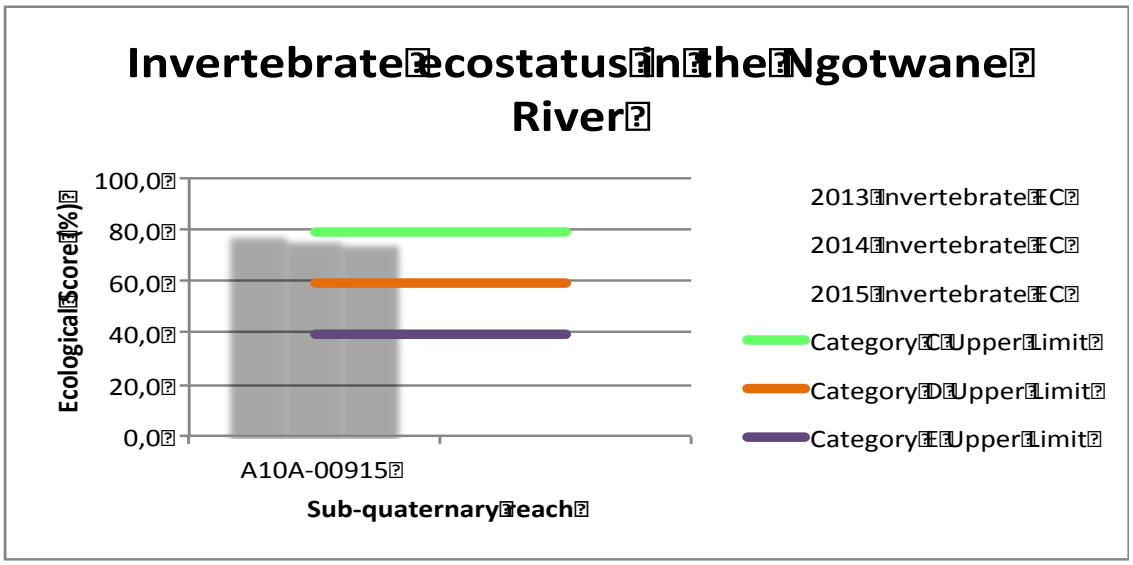


FIGURE 10-5. ECOLOGICAL STATE OF THE MACRO-INVERTEBRATES IN THE NGOTWANE RIVER

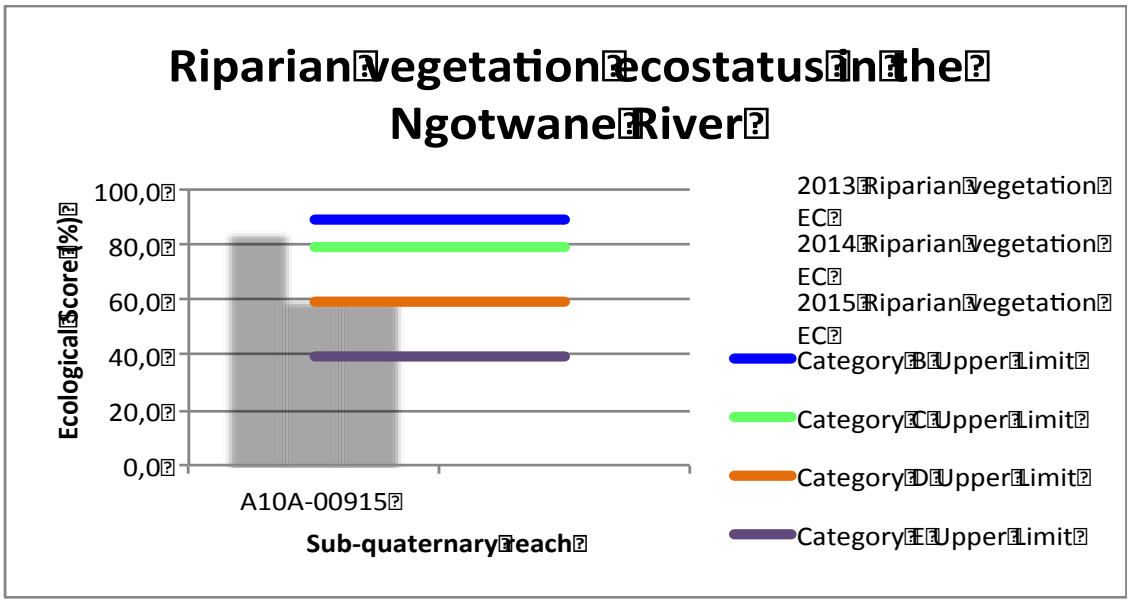


FIGURE 10-6. ECOLOGICAL STATE OF THE RIPARIAN VEGETATION IN THE NGOTWANE RIVER

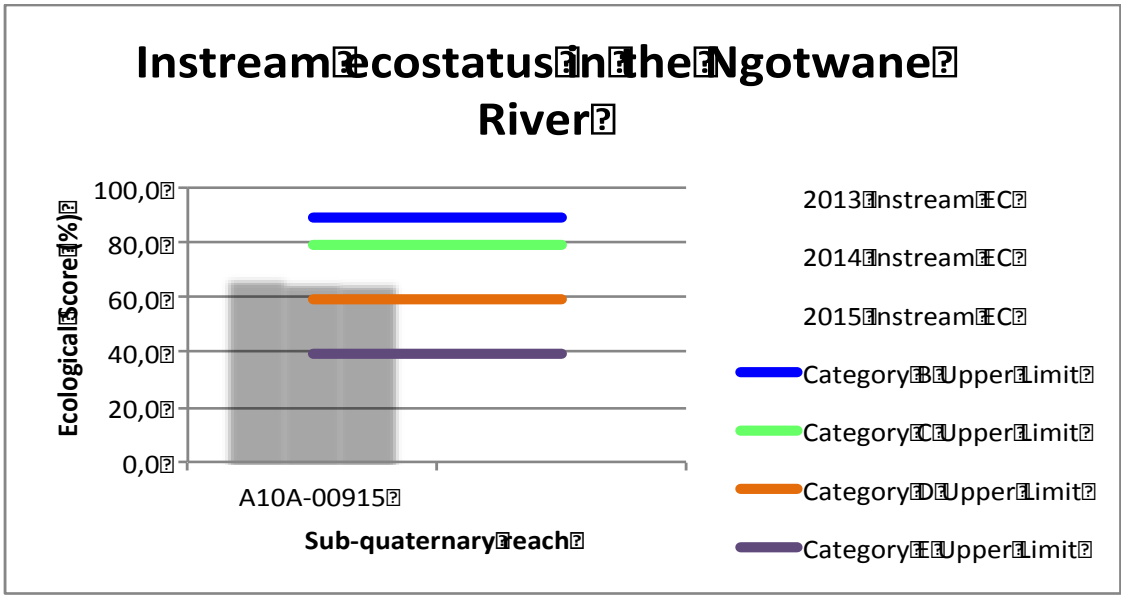


FIGURE 10-7. INSTREAM ECOLOGICAL HEALTH IN THE NGOTWANE RIVER

10.2.1 MONITORING RESULTS: REACH A10A-00915 (REPRESENTED BY A1NGOT-DINOK)

	
APRIL 2013	JUNE 2014 (siltation)
	
SEPTEMBER 2014	MARCH 2015

FIGURE 10-8. SITE A1NGOT-DINOK (A10A-00915)

GENERAL DESCRIPTION

This site is situated downstream of an eye, in close proximity to a rural settlement in the upper Ngotwane catchment.

FISH

This site was surveyed during April and August 2013, June and September 2014, and March 2015. The PES and EC (52.5% D) remained constant, although the FROC of one species (*Pseudocrenilabrus philander*) has increased since the start of the study as it occurs in high numbers in certain areas, especially in SS (slow shallow) vegetated areas.

Slightly lower flow was observed during March 2015, and there was some increase in SS habitat which positively affects the FROC of especially one species – PPHI – as it was sampled in high numbers.

All the expected fish species are expected to still be present within this SQ Reach although the Frequency of Occurrence (FROC) of some species has been reduced slightly from reference conditions. Reduced FROC's were given mostly for species with a preference for SD and FD habitats, as these habitats are mostly absent or sparse. Species with a preference for water column also received reduced FROC's, as the water level seems to be too shallow for adequate cover. Flow modification may be an issue resulting in lower water levels.

There is some siltation/sedimentation and algae growth present at the site which negatively impact on the substrate quality. Enrichment and habitat trampling (from local cattle grazing) also plays a role in the abundance and occurrence of species.

MACROINVERTEBRATES

A very small change to the overall EC is observed from 2014 to 2015, with impacts mostly observed in the water quality metric and minimal changes to taxa with a preference for standing water, as well as to the abundance and/or frequency of occurrence of those taxa with a preference for the riparian vegetation.

Fourteen data sets from 2005 to 2014 were used to run the MIRAI to derive the PES of C. Changes observed from 2013 to 2014 are mainly changes to the flow metric as can be seen by the responses of the macroinvertebrates. Changes to taxa showing preferences for all four types of flow, i.e. very fast, moderate, slow and standing water, are observed. This is due to the fact that there was very little flow present during the June and September 2014 sampling events. Abstraction and flow diversion occurs upstream from the site.

RIPARIAN VEGETATION

Marginal Zone

Sedges and grasses are dominant. Individual trees and shrubs occur in places. Vegetation cover is good adjacent to a shallow channel. The hydrological environment is reasonably stable due to an eye being the main driver, although a large portion of this water is being diverted for use by the community. Substrate consists of tufa rock material with pockets of highly organic material (peat). Signs of stock grazing and trampling are visible. Human activities occur in the form of washing of clothes, footpaths and water collection points. Zone is dominated by *Pycreus nitidus, Imperata cylindrica, Fimbristylis dichotoma, Cyperus fastigiatus, Cyperus sexangularis, Juncus lomatophyllus, Schoenoplectus muricinux*, etc. Woody species include *Searsia lancea,*

Combretum erythrophyllum, etc. Of concern is an increase in exotic vegetation (dominated by *Populus x canescens*), as well as terrestrialization taking place by species such as *Diospyros lycioides, Euclea crispa,* etc. due to the drying out of the system as a result of the diversion of water.

Non-marginal Zone

Grasses and sedges dominate, with scattered trees and shrubs. The dominant grasses in the zone include *Imperata cylindrica*, *Sporobolus africanus* and *Andropogon eucomus*. There is good vegetation cover and abundance. Scattered trees consist of *Acacia robusta, Ziziphus mucronata, Diospyros lycioides, Combretum erythrophyllum*, *Searsia lancea*, *Searsia pyroides*, etc. Substrate consists of highly organic soil and tufa rock. Exotic species are present such as *Eucalyptus grandis*, *Populus x canescens, Acacia mearnsii*, *Zinnia peruviana*, etc. Of concern is terrestrialization with a visible increase in *Acacia karoo* numbers and also an increase in *Populus x canescens*. Grazing and trampling have resulted in less grass cover and signs of erosion are visible.

The overall vegetation health is in a C/D category with a negative trend.

WATER QUALITY

The water quality at Site A1NGOT-DINOK also falls into a category A (High quality) dominated by taxa typical of well oxygenated, oligo- to mesotrophic waters with low to moderate electrolyte content such as *Encyonopsis cesatii, Achnanthidium minutissimum Cymbella kappii* and *Encyonopsis subminuta*. The minor presence of *Nitzschia amphibia*, a species linked to fertiliser runoff suggests that the ecological category for this site should be allocated an A/B (High quality).

10.2.2 IMPACTS, THREATS AND MANAGEMENT PRIORITIES IN THE NGOTWANE RIVER CATCHMENT

The main impacts resulting in the loss of ecological health include:

- Decreased flow at site, creating very shallow stream, due to upstream municipal abstraction.
- Siltation due to cattle trampling and grazing.
- Nutrient enrichment, due to cattle, rural activities, such as washing clothes in stream.
- Increased turbidity and bank erosion, due to cattle trampling/grazing and vegetation removal.
- Terrestrialisation of the riparian zone, due to diversion of water out of the wetland and riparian zone.

Management intervention is required to prevent further degradation of the resource. These include:

- Regulation and control of abstractions.
- Implementation of ecological flow requirements.
- Awareness creation and education regarding the importance of river systems for community health and upliftment.
- Management of land-use practices, including abstraction, cattle grazing and washing in the rivers.

11 RESULTS IN THE MOLOPO SUB-MANAGEMENT AREA

The Molopo sub-management area corresponds to the catchment of the Molopo River. Main tributaries in this catchment include the Ramatlabama, Polfonteinspruit and Madebe rivers (Figure 11-1). The Molopo River rises from the Molopo Eye near Mafikeng and flows westwards to form the northern border of the North West Province with Botswana. The Molopo River is a tributary of the Orange River. It ceases as a surface flow and discharges into pans in Botswana before turning south and emerging as surface flow just before it reaches the Orange River.

The source of the Molopo River is the main supplier of water to the town of Mafikeng. Irrigation is also a major water demand in this sub-management area.

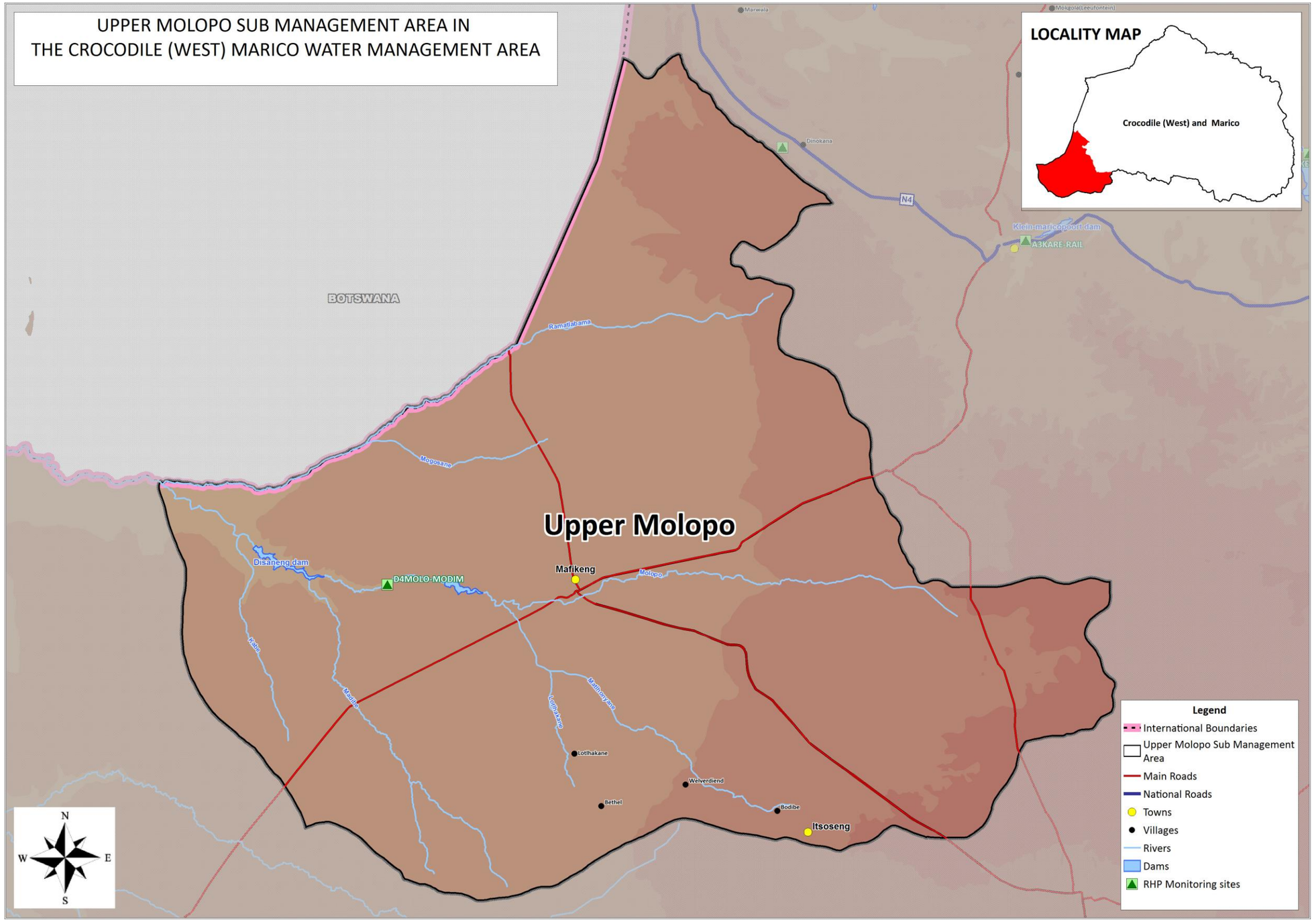


FIGURE 11-1. OVERVIEW OF THE MOLOPO SUB-MANAGEMENT AREA

11.1 RIVER HEALTH MONITORING SITES IN THE MOLOPO SUB-MANAGEMENT AREA

One monitoring site was selected in the Molopo River sub-area.

Table 11-1 provides the sub-quaternary reaches within the Molopo sub-area and the River Health Monitoring Site that has been sampled over the project period.

TABLE 11-1. SUB-QUATERNARY REACHES AND RIVER HEALTH MONITORING SITE IN THE MOLOPO SUB-AREA

MONITORING SITE	SQR REACH	RIVER NAME	SQR NUMBER	LATITUDE	LONGITUDE
	D41A-01017	Mogosane	MO04.02		
	D41A-01132	Kabe	MO03.01		
	D41A-01138	Molopo	MO01.00		
	D41A-01180	Polfonteinspruit	MO01.01		
	D41A-01181	Lotlhakane	MO01.02		
	D41A-01247	Madibe	MO02.01		
	D41A-01251	D41A-01251	MO02.02		
	D41A-00961	Ramatlabama	MO04.01		
D4MOLO-MODIM	D41A-01055	Molopo	MO02.00	25.449886°	25.859247°
	D41A-01148	Madibe	MO02.03		
	D41A-01160	Lotlhakane	MO01.03		
	D41A-01079/Ramatlabama	Ramatlabama	MO04.03		
	D41A-01079/Molopo	Molopo	MO04.00		
	D41A-01123	Molopo	MO03.00		

11.2 ECOLOGICAL HEALTH OF THE MOLOPO RIVER SUB-AREA

The ecological health of the river reach D41A-01055 is in a D category (Figure 11-1). Extrapolations to the remaining reaches in the catchment were not conducted during this phase of the study. The condition remained fairly stable within the 3-year monitoring period (Figure 11-2- Figure 11-6), however the system is in a negative trend and will fail if management intervention, described below is not undertaken. The fish is already in an unsustainable E category (Figure 11-4), due to lengthy periods of no flow and poor water quality.

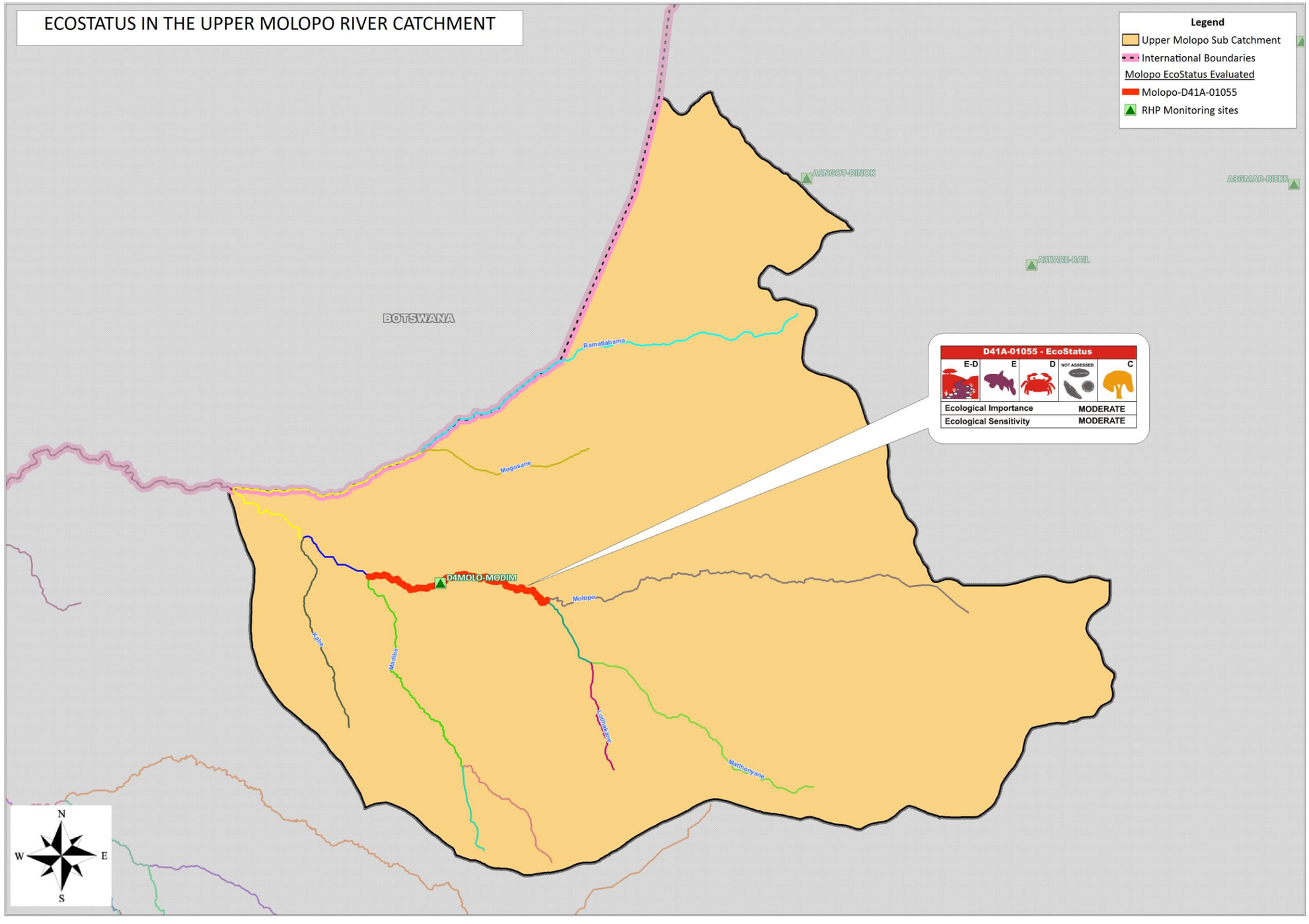


FIGURE 11-2. ECOLOGICAL STATUS OF THE MOLOPO RIVER CATCHMENT

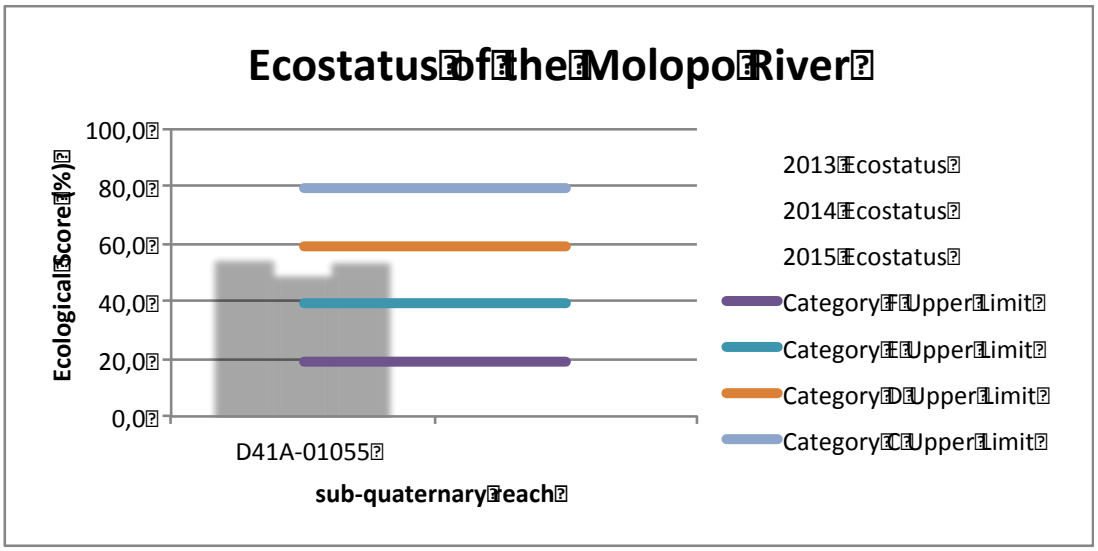


FIGURE 11-3. ECOSTATUS OF THE MOLOPO RIVER REACH D41A-01055

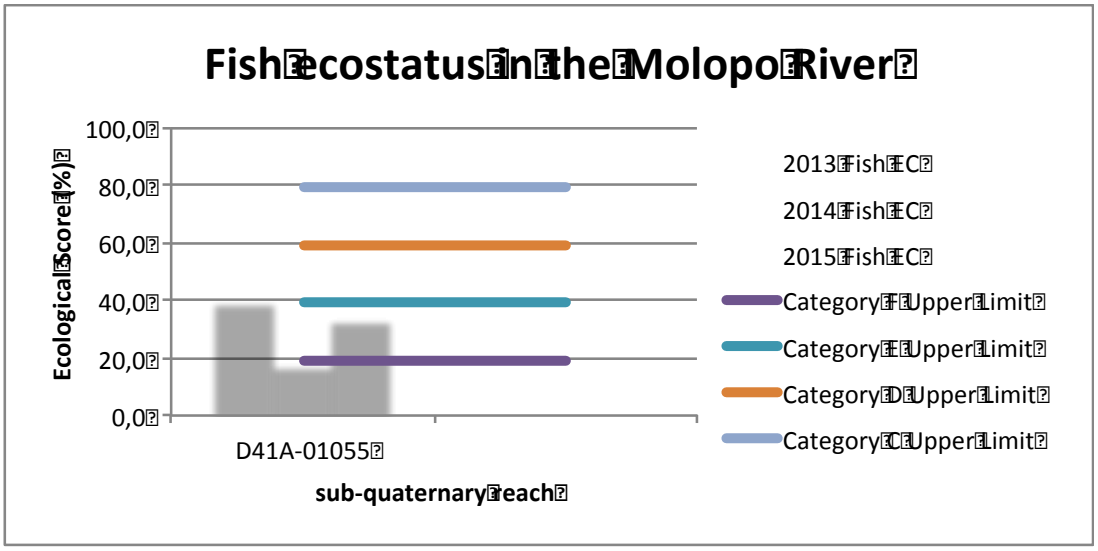


FIGURE 11-4. ECOLOGICAL STATE OF THE FISH IN THE MOLOPO RIVER REACH D41A-01055

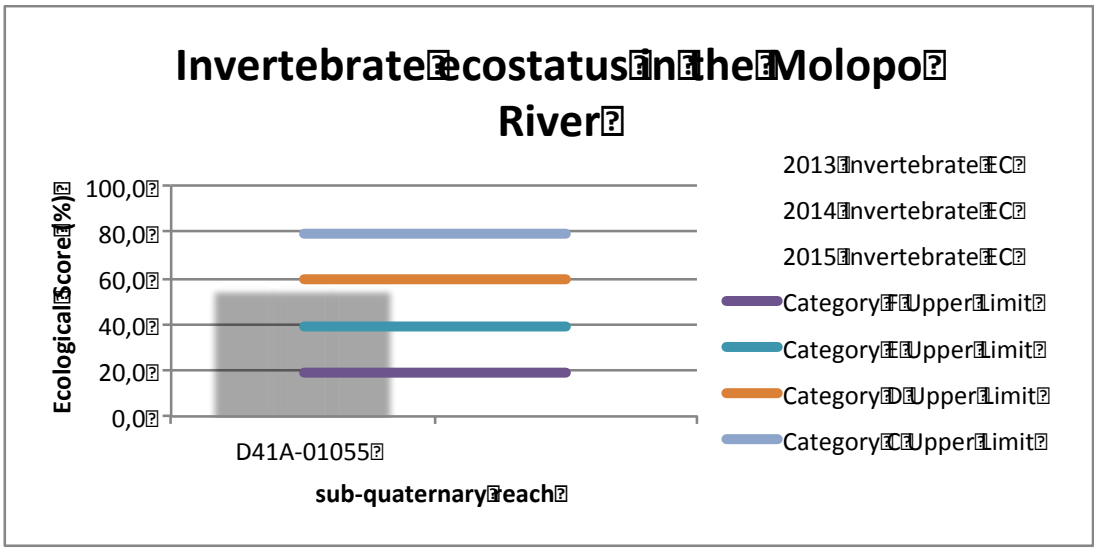


FIGURE 11-5. ECOLOGICAL STATE OF THE MACO-INVERTEBRATES IN THE MOLOPO RIVER REACH D41A-01055

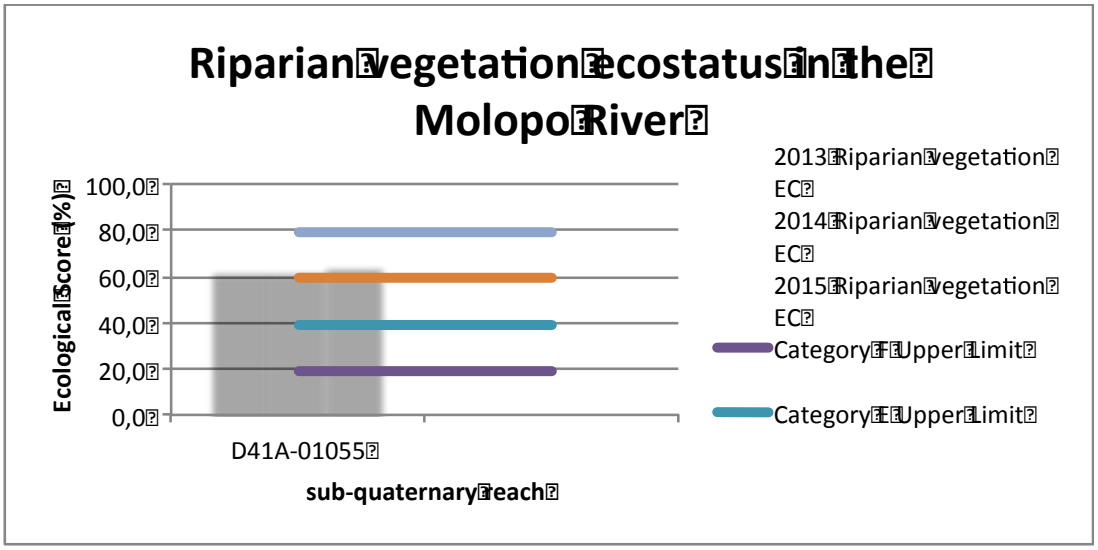


FIGURE 11-6. ECOLOGICAL STATE OF THE RIPARIAN VEGETATION IN THE MOLOPO RIVER REACH D41A-01055

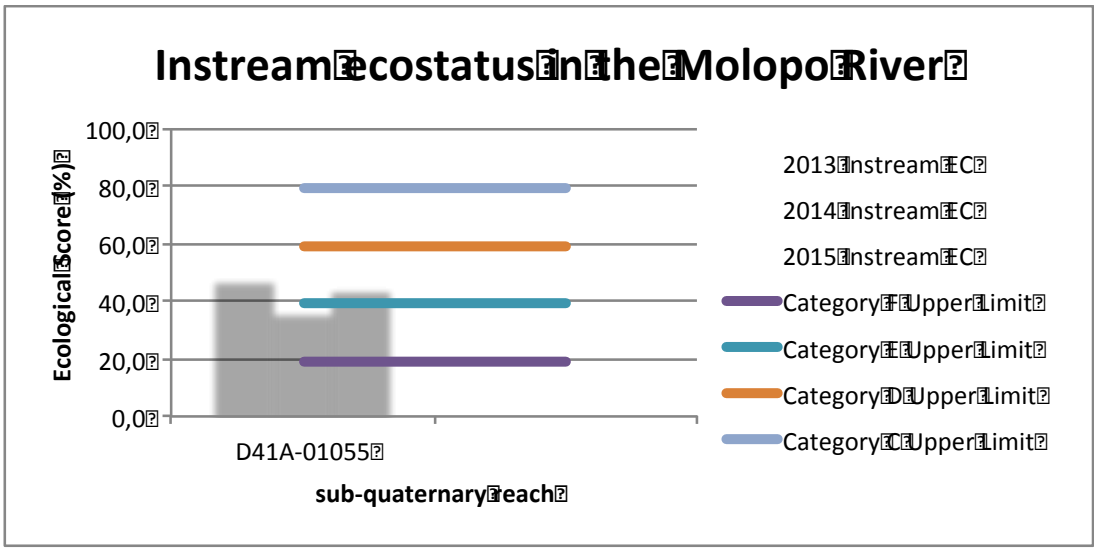


FIGURE 11-7. INSTREAM ECOLOGICAL HEALTH IN THE MOLOPO RIVER REACH D41A-01055

11.2.1 MONITORING RESULTS: REACH D41A-01055 (REPRESENTED BY D4MOLO-MODIM)

AUGUST 2013

JUNE 2014

SEPTEMBER 2014	MARCH 2015

GENERAL DESCRIPTION

This site is situated on the Molopo River, in a rural area, between two dams downstream of Mafikeng. The site forms part of a greater channelled valley-bottom wetland, A. Linstrom, *Pers. comm.,* April 2013. At the time of both field visits, namely during April and August 2013, no flow was present, with only shallow pools occurring on site.

FISH

This site has been visited during April and August 2013, June and September 2014, and March 2015. No change in its EC was observed during the 2013, 2014, and 2015 surveys. The site is usually dry.

Four of the four expected fish species may be expected to still occur during more favourable conditions within this SQ Reach although the Frequency of Occurrence (FROC) of the species has been reduced largely from reference conditions.

Flow modification, in this case low flows, results in poor habitat quality, poor water quality, loss of habitat integrity, and loss of species.

Poor water quality, due to pollution from the area and Mafikeng, enrichment and sedimentation plays a role in decreased abundance and occurrence of species.

The fish is currently in an unsustainable E category and deterioration will continue under current conditions and flow regimes.

MACROINVERTEBRATES

Four historic data sets were used to run the MIRAI and derive an EC of D. The most impaired metric is that of water quality which is largely impacted at 41.5%, followed by instream habitat and flow modification. Taxa that have a high requirement for unmodified physico-chemical conditions and that are absent in the reach include Prosopistomatidae, Heptageniidae and Pyralidae. Presence of taxa preferring standing water, i.e <0.1m/s are heavily impacted and include Leptophlebiidae, Caenidae, Lestidae, Chlorolestidae, Planorbinae, Lymnaeidae and Thiaridae. The occurrence of taxa preferring cobbles and vegetation is also heavily impacted. Overall, the water quality driver seems to be contributing most to the impairment of the river in this reach, as is reflected in the absence of water quality sensitive taxa, as well as those taxa that have a moderate to low requirement for unmodified physic-chemical conditions.

MIRAI was not re-run during 2014 and 2015 due to no additional SASS data available. This was because no sampling was conducted due to a dry site.

RIPARIAN VEGETATION

Marginal Zone

Sedges & grasses dominate. The dominant sedges are *Cyperus fastigiatus, Berula erecta, Gomphrena fruticosus, Schoenoplectus muricinux, Cyperus eragrostis*, etc. and grass species include *Paspalum urvillei, Themeda triandra, Bothriochloa insculpta, Eragrostis gummiflua*, etc. Vegetation occurs in clumps next to an incised marginal zone with bare surface areas in between. Muddy soils and murky water are present. Substrate consists of soil. Incised channel shows signs of erosion. Human activities in the form of footpaths are visible. Cattle farming has resulted in trampling and overgrazing. A crossing for people and cattle has resulted in surface erosion. No woody species occur in this zone. Exotic pioneers are present (*Xanthium strumarium, Verbena officinalis, Tagetes minutes, Flaveria bidentis, Xanthium spinosum,* etc.).

Non-marginal Zone

Grass-dominated state with species such as *Sporobolus africanus, Eragrostis plana, Cynodon dactylon*, etc. It appears that the exotic *Gomphrena fruticosus* is increasing in numbers. Both banks form part of a bigger valley bottom floodplain wetland. Overgrazing and trampling, and the lack of a proper fire regime impact on species composition and cover. Some exotic pioneers are present. Few trees occur, with scattered shrubs visible. The woody species consist of *Ziziphus mucronata* and *Acacia hebeclada.* Bank substrate consists of heavy clay soil.

The overall vegetation is in a C category with a negative trend.

WATER QUALITY

No diatom sampling was conducted at this site.

11.2.2 IMPACTS, THREATS AND MANAGEMENT PRIORITIES IN THE MOLOPO RIVER SUB-AREA

The main impacts resulting in the highly modified state of the Molopo River includes:

- Dams in the catchment affecting the natural flow regime and resulting in habitat impairment and loss and species abundance and loss.
- Poor sanitation and sewage return flows
- Lack of solid waste management
- Erosion due to over grazing

Management intervention required toe maintain/improve the Molopo River include:

- Regulation and control of abstraction and dam operation in catchment, to prevent no flow for extend periods.
- Implementation of ecological flow requirements.
- Management of land use practices, such as cattle grazing.

12 THE RHAM (RAPID HABITAT ASSESSMENT METHOD)

12.1 INTRODUCTION

The RHAM is a relatively rapid method of quantifying the instream habitat at a site, including the substrate, cover and velocity-depth characteristics of the site being assessed (DWA, 2009). The RHAM is a method within the new REMP (River Ecostatus Monitoring Programme), previously known as the River Health Programme (RHP). The REMP is more aligned with current water resource management approaches, such as the Classification system, determination of the Ecological Reserve, as well as Resource Quality Objectives (RQOs).

The RHAM has developed during the course of the project and was applied to four of the monitoring sites within the Crocodile (West) Marico catchment. RHAM was assessed at sites where flow was sufficient during the duration of the project. Four sites were chosen to apply the full RHAM to, during a workshop scenario. As part of the RHAM model, TPCs (Thresholds of Potential/Probable Concern) for various components are also determined, including the instream and riparian IHI, physico-chemical, fish, macroinvertebrate, riparian vegetation and Ecostatus components. Specialist knowledge of the system and the relevant component are used to determine the relevant TPCs.

12.2 THE TPC FRAMEWORK

Ecological Specifications (EcoSpecs) are broad ecological objectives that are developed for a particular resource and can be in the form of numerical values or narrative statements or both (Kleynhans & Louw, 2007). EcoSpecs are set for a specific Ecological Category. TPCs are usually set at the lower range of the EcoSpecs. TPCs function as a "red flag" or warning system within a DSS (Decision Support System) and allow for timeous management response within a resource management framework.

TPCs represent hypotheses of the limits of acceptable change in ecosystem structure, function and composition (Rogers & Biggs, 1999) and are seen as the upper and lower levels within a continuum of change (Bohensky *et al.,* 2009). It is important to note that TPCs are considered to be flexible end-points and therefore should be adapted, challenged and refined as necessary (Rogers & Biggs, 1999).

A Decision Support System (DSS) is required in order to implement the TPC framework. This allows for interpretation of monitoring data and to determine whether the goals and objectives for the resource are being met. It also allows for management decisions to be taken if necessary.

Figure 12-1 gives an example of a DSS for habitat and biological monitoring (Kleynhans & Louw, 2009). The habitat and biological data collected should be assessed to determine whether the TPCs have been reached/exceeded or not. If not, then level 1 monitoring should continue. If the habitat TPCs have been reached/exceeded, then a level 2 assessment should be implemented, including recording quantitative habitat measurements per macro-habitat unit, physic-chemical measurements and environmental indicators assessed. Once this has been completed and if the habitat TPCs are still exceeded, then the level 3 assessment should be undertaken, namely that of assessing the biological responses, which include the fish and macroinvertebrates, and to determine if the REC has been attained. If the biological TPCs are exceeded, then the level 4 assessments should be implemented, i.e. to determine the potential cause of the situation, including more intensive surveys. If the cause is located, then appropriate management action should be taken, if not, then monitoring should continue until the cause of the problem is determined. Management action may include adapting the relevant RQOs, EcoSpecs and TPCs and monitoring the outcome of these actions.

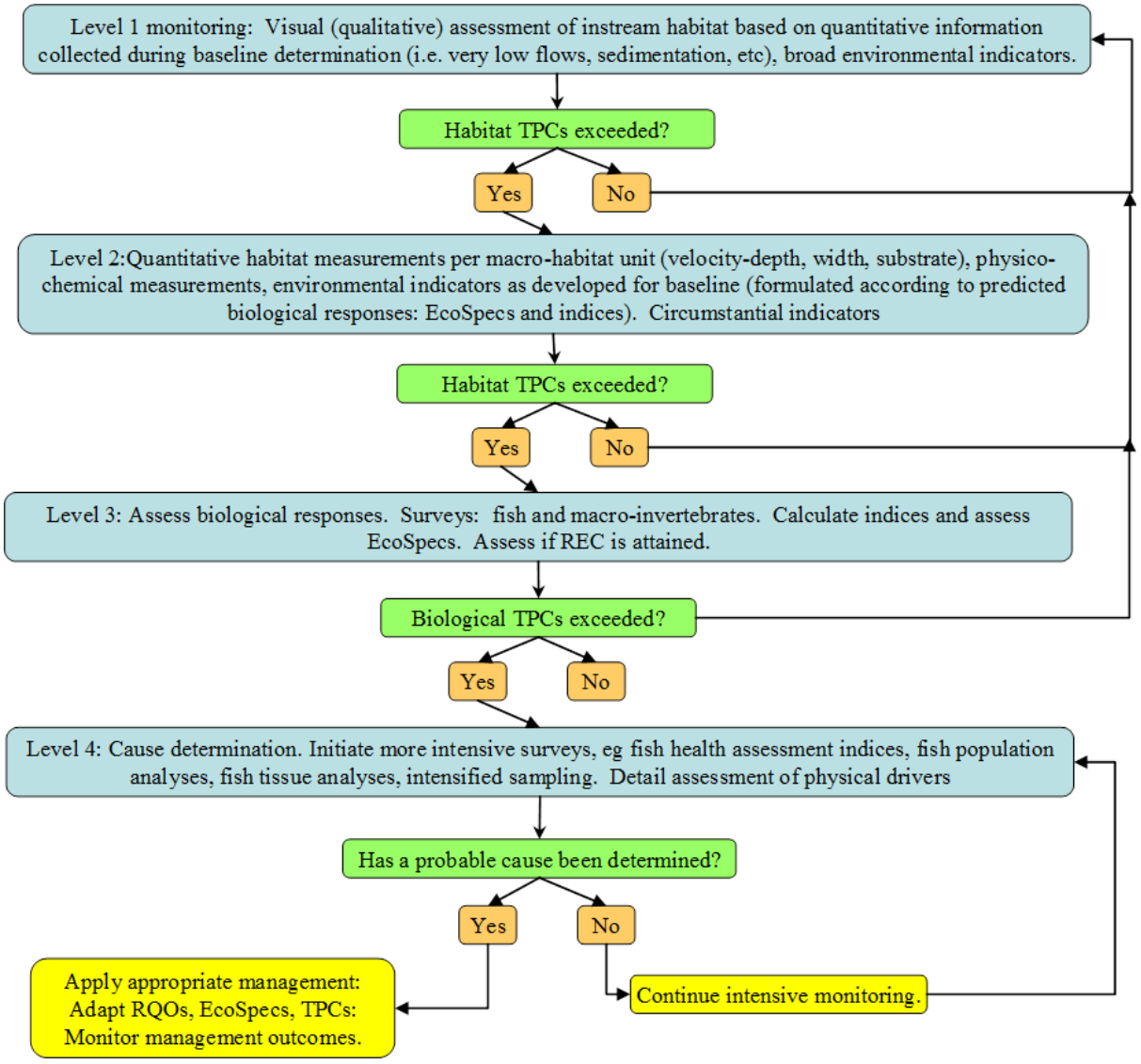


FIGURE 12-1. EXAMPLE OF A DECISION SUPPORT SYSTEM FOR HABITAT AND BIOLOGICAL TPC IMPLEMENTATION (KLEYNHANS & LOUW, 2009).

12.3 RHAM METHODOLOGY

The RHAM methodology involves the measurement of instream habitat characteristics as per cross-section/s through the relevant Geomorphic Habitat Units (GHUs) available at a site (Kleynhans, 2015). A GHU can consist of a pool, run, riffle, rapid, or any combination of these, for example run/riffle. Depending on time and budget constraints, many cross-sections can be taken through different or the same GHU. In this project, a maximum of two cross-sections were taken in GHUs at some sites. Various measurements are taken at regular intervals (point distances) across the cross-section using a transparent Head Velocity Rod, including the depth, maximum and minimum hydraulic heads at each point in the cross section. The intervals can vary depending on the width of the stream/river. The hydraulic head difference at each point is used to calculate a general velocity (m/sec) at the point. This allows the calculation of velocity-depth classes for fish and

macroinvertebrates. At each interval, the substrate type is noted within a 30cm radius of the perspex rod. Substrate types include roots, fines, sand, gravel, cobble, boulder, bedrock, woody debris, detritus, whether the substrate is embedded or covered in algae or not, instream vegetation, overhanging vegetation, undercut banks and root wads. These data are then entered into the RHAM model to produce quantitative estimates of the physical substrates and velocity-depth classes present at the site. The coordinates of the cross-section are also determined.

The RHAM model consists of various sheets, including the index, user guide, site information where the *in situ* water quality parameters are inserted, TPCs and targets for selected water quality parameters, a site drawing, the cross-section input, longitudinal input and analyses, the instream and riparian IHI as well as targets for each of these. It is important to note that not all of the IHI parameters need to have targets and TPCs – it is up to the specialist to decide which parameters/habitat components are relevant/ important for the site being assessed.

For the fish RHAM component, a reference fish species list is derived, as well as fish sampling effort and fish species sampled. The percentage substrate per velocity depth class is indicated, as well as the fish indicator species selected for the particular site, with various graphs generated depicting the different criteria. Fish targets and TPCs are determined.

For the macroinvertebrate component, a reference list of taxa is derived, the biotope ratings entered, taxa sampled entered into the RHAM, indicator taxa selected and targets and TPCs derived per indicator taxon. Graphs are also derived, for example the % substrate per velocity depth class or a graph depicting the specific cross-section as it related to macroinvertebrate flow classes.

The riparian vegetation component includes the VEGRAI procedure, a description of the reference condition, riparian vegetation modification ratings, marginal-, non-marginal- , woody- and non-woody species, macrophytes and the riparian zone EC, including targets and TPCs.

The site Ecostatus is then determined, for the fish, macroinvertebrates, instream Ecostatus, riparian vegetation and the overall site Ecostatus. Targets and TPCs are also set for each of these.

One of the final RHAM sheets includes information regarding which targets and TPCs are not met per component, per GHU, per site visit. Fish scientific names are also included in the model.

Photos for the site are included in a separate file that is hyperlinked to the RHAM model. Instructions for the photo file are available on the Index sheet of the RHAM model.

For in-depth detail regarding the RHAM methodology, please consult Kleynhans, 2015.

12.4 RHAM SITES ASSESSED

The four sites that were assessed using the RHAM model are all existing EWR sites as follows:

- A3 KAAL-RIETS;
- A3 GMAR-KOEDO;
- A2 ELAN-KLIPB;
- A2 HEXR-ROOIW.

The reason that only four sites were selected to assess using the RHAM model is because not all sites were suitable for RHAM measurements and of those at which measurements were taken; only four were selected due to budgetary constraints. The RHAM data collected for the sites not assessed using the RHAM model will be available for assessment for future RHAM surveys and analyses.

It is important to note that the RHAM is derived at site level and the component models, namely IHI, FRAI, MIRAI & VEGRAI are also derived at site level for the relevant four sites.

Models derived and represented at SQR level are relevant and used to describe and assess the SQRs for the project.

Summarised information derived from the RHAM is presented for the IHI, fish, macroinvertebrate, riparian vegetation and EcoStatus components, each with targets and TPCs indicated. Detailed information per component can be derived from the relevant RHAM model.

The final RHAM models per site are included in the information and data submitted per site for this project.

12.4.1 A3 KAAL-RIETS

This site was assessed on five different occasions from 2013 – 2015. Two cross-sections were measured, both in the run GHU, numbered 1.01 and 1.02 respectively.

FIGURE 12-2. CROSS-SECTION 1.01 IN THE RUN GHU, A3KAAL-RIETS

12.4.1.1 INSTREAM AND RIPARIAN IHI

The site-based IHI can be used to indicate change over a period of time. For this site, the IHI remained constant, with very little change taking place over the duration of the project.

For the instream IHI, targets and TPCs were derived for the following components (Figure 12-3).

Water abstraction, bed modification, flow modification, and physico-chemical modification.

These components were considered important for this site, in terms of potential modification due to land-use in the adjacent and upper catchment.

The instream IHI Target was set at 82% and the TPC was set at 83%, thus a B instream IHI ecological category was set as the target for this site. At no time during the project has this B category been compromised for the instream habitat component.

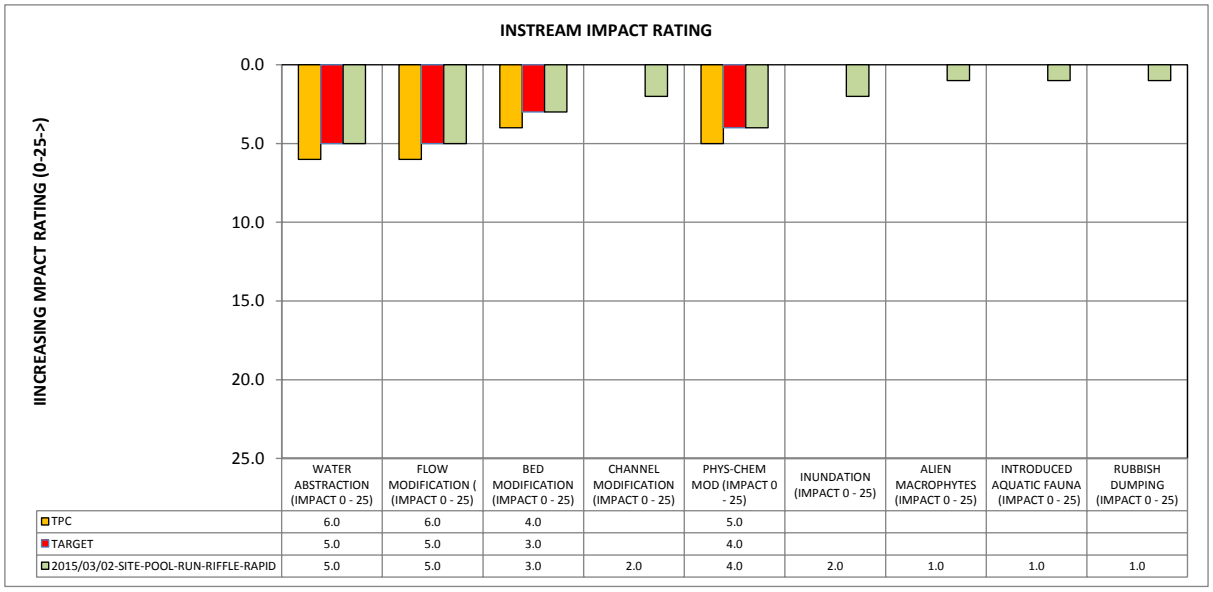
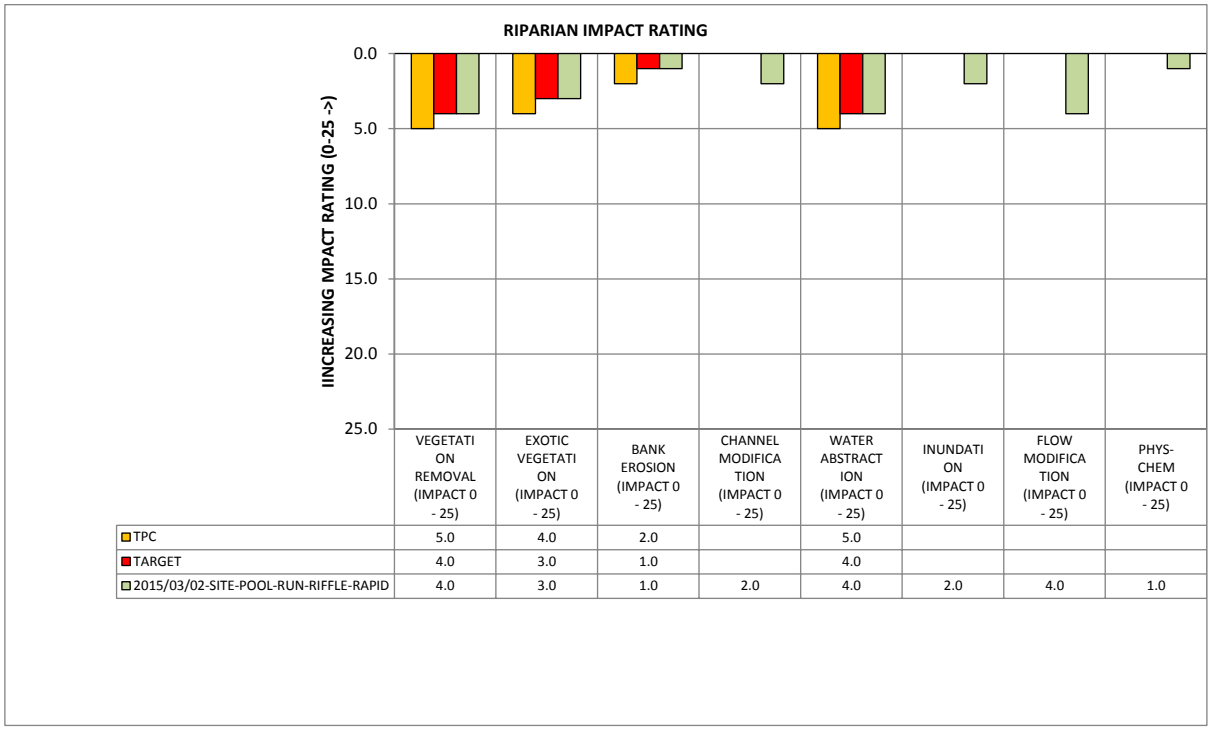


FIGURE 12-3. INSTREAM TARGETS & TPCS FOR SELECTED PHYSICO-CHEMICAL INSTREAM IHI COMPONENTS

For the riparian IHI, targets and TPCs were derived for the following components:

Vegetation removal, exotic vegetation, bank erosion and water abstraction (Figure 12-4). These components of the riparian vegetation were considered important for this specific site in terms of the land-use and potential impacts at the site.



	VEGETATION REMOVAL (IMPACT 0 - 25)	EXOTIC VEGETATION (IMPACT 0 - 25)	BANK EROSION (IMPACT 0 - 25)	CHANNEL MODIFICATION (IMPACT 0 - 25)	WATER ABSTRACTION (IMPACT 0 - 25)	INUNDATION (IMPACT 0 - 25)	FLOW MODIFICATION (IMPACT 0 - 25)	PHYS-CHEM (IMPACT 0 - 25)
TPC	5.0	4.0	2.0		5.0			
TARGET	4.0	3.0	1.0		4.0			
2015/03/02-SITE-POOL-RUN-RIFFLE-RAPID	4.0	3.0	1.0	2.0	4.0	2.0	4.0	1.0

FIGURE 12-4. RIPARIAN TARGETS & TPCS FOR SELECTED RIPARIAN IHI COMPONENTS

The riparian IHI EC was determined as an A/B at 89.6%, with a target set at 85% (B category) and a TPC set at 88%. The targets and TPCs were met all of the time for the riparian vegetation IHI, according to the TARG/TPC/REP sheet which summarises the targets and TPCs over the total assessments and indicates which of the targets and TPCs are met or not met per component.

Fish

Fourteen fish species are expected under reference conditions for this site, with a minimum of three species sampled in August 2013 and a maximum of five species sampled in September 2014 and March 2015 respectively. The fish EC for the project duration varied from 89.5% (A/B category) in April 2013 to 97.5% (A category) in August 2013. The FRAI target was set at 93% (A category) with the related TPC set at 94%. Both the FRAI target and TPC were not met in April 2013, with the remaining fish survey targets and TPCs all being met (RHAM sheet TARG/TPC/REP), except for the FRAI TPC not met during March 2015.

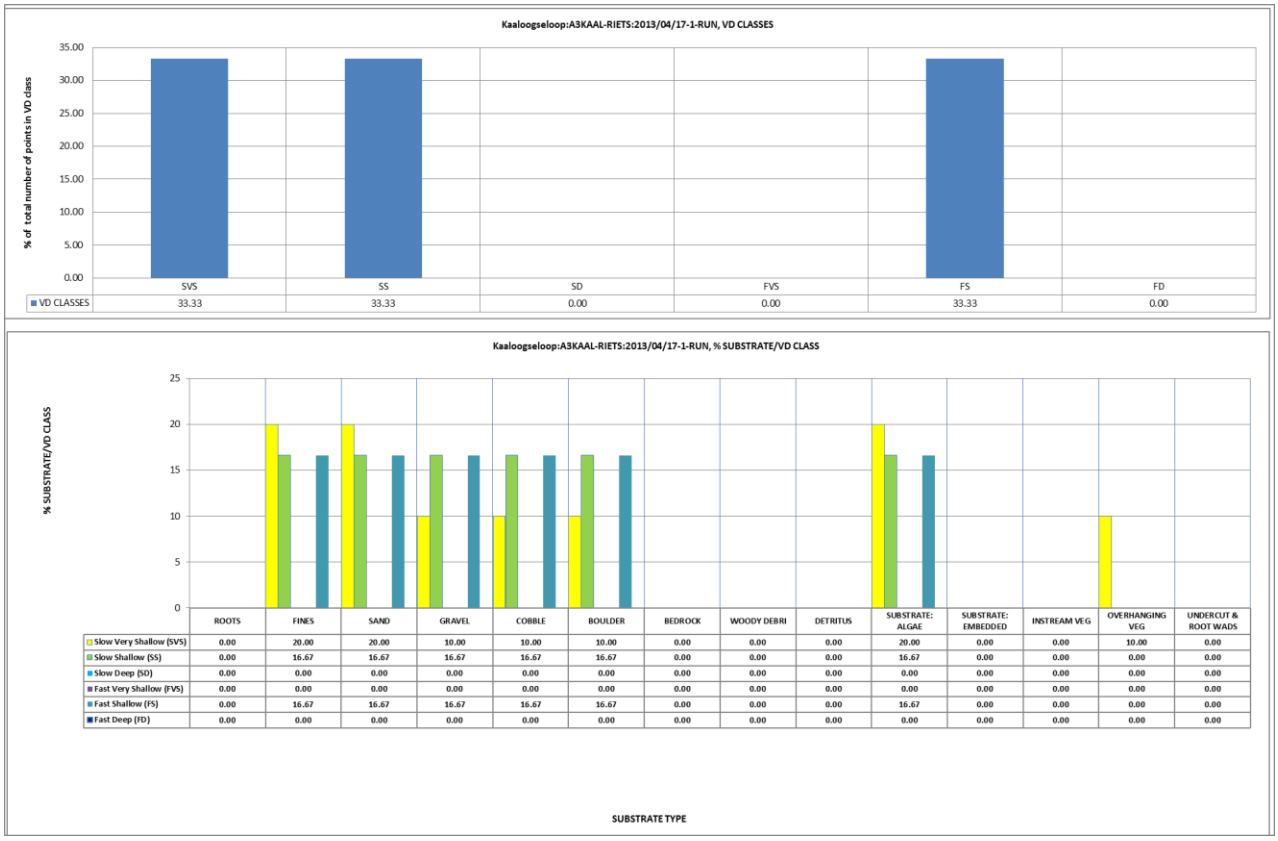


FIGURE 12-5. PERCENTAGE OF TOTAL NUMBER OF POINTS IN VELOCITY-DEPTH CLASSES (TOP GRAPH) AND % SUBSTRATE PRESENT PER VELOCITY-DEPTH CLASS (BOTTOM GRAPH)

In April 2013, the velocity-depth habitat in the run GHU 1.01, the slow very shallow, slow shallow and fast shallow habitats occurred in equal proportions (33.33%). No slow deep, fast very shallow and fast deep habitat present at the site (Figure 12-5). Fines and sand dominated the available substrate, followed by gravel, cobble and boulder substrate. Some overhanging vegetation was present. Algae (diatoms) were also present in all slow habitats.

Macroinvertebrates

Macroinvertebrates were sampled in all available RHAM habitats, namely that of pool, run, riffle and rapids during five different sampling events between 2013 – 2015. The MIRAI EC for all sampling events is a category B, with the MIRAI target set at 83% (B category) and the TPC set at 85%. Both the target and TPC is met during all five sampling events (TARG/TPC/REP sheet). The minimum SASS total score target was set at 170 and the TPC set at 175, while the minimum ASPT target was set at 5.8 and the ASPT TPC was set at 6.0. Indicator taxa selected for the site include Coenagrionidae, Dytiscidae, Gomphidae, Heptageniidae and Psephenidae. These taxa are considered representative of available biotopes at the site, as well as generally present in fair abundances and fairly sensitive to flow and water quality conditions to varying degrees. Some of the indicator taxa are not present during certain sampling events, for example during April 2013 the Coenagrionidae and Heptageniidae are absent at the site.

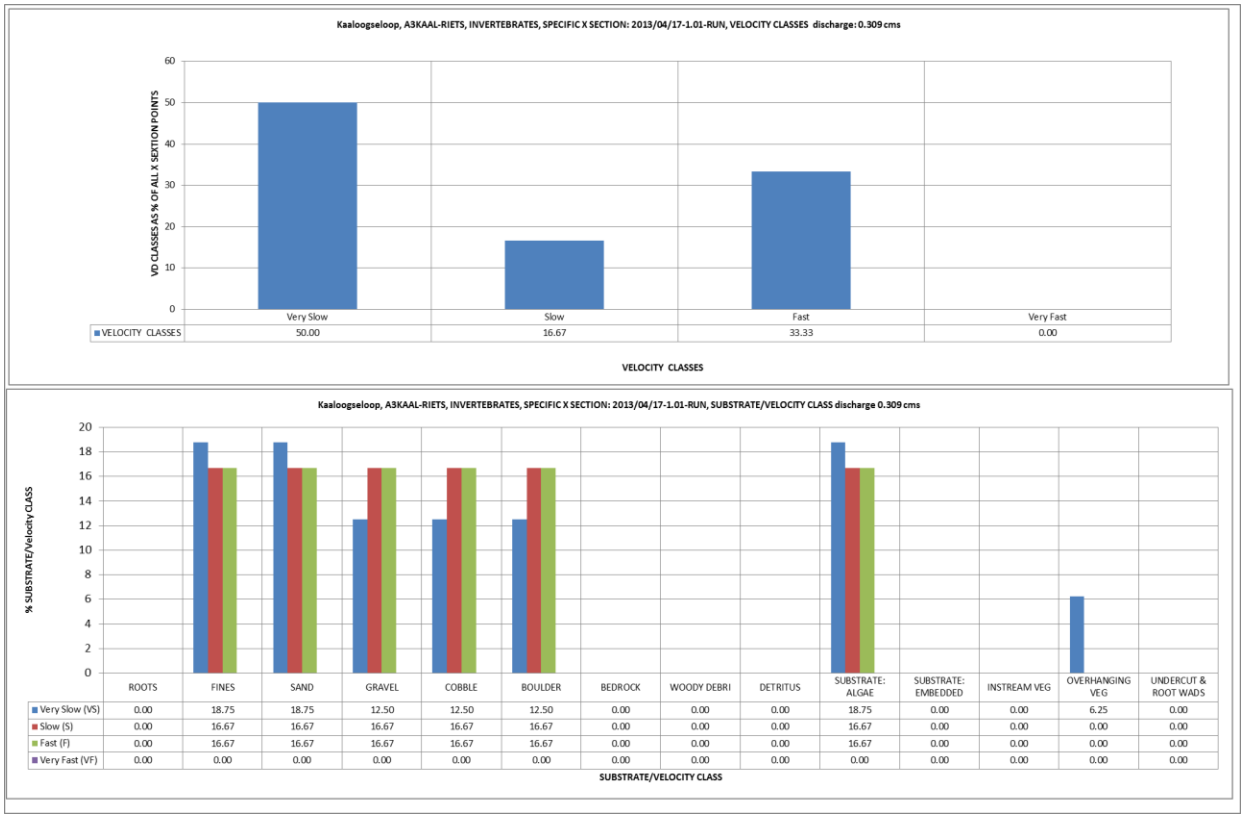


FIGURE 12-6. VELOCITY-DEPTH CLASSES AS A % OF ALL CROSS-SECTION POINTS (TOP GRAPH) AND % SUBSTRATE PRESENT PER VELOCITY-DEPTH CLASS (BOTTOM GRAPH), FOR MACROINVERTEBRATES AS AT 17 APRIL 2013

The very slow velocity class is dominant at 50%, followed by fast at 33.33% and slow at 16.67%. No very fast flow occurs at the cross section. Fines and sand dominate the substrate at the cross section, followed by gravel, cobble and boulder substrate. No instream vegetation or bedrock is present.

Riparian vegetation

The riparian vegetation was assessed annually, with three different assessments conducted between 2013 – 2015. The VEGRAI for all three assessments was calculated at 77.76% (C category), with the target set at 85% (B category) and the corresponding TPC set at 88%. This means that none of the targets are met during any of the assessments (TARG/TPC/REP).

Physico-chemical

Targets and TPCs were set, using fish species requirements for the relevant physic-chemical parameter. Reference is made to the following: Department of Water Affairs and Forestry, 2008. Methods for determining the Water Quality component of the Ecological Reserve. Guidelines from the publication were used to set the targets and TPCs. The guidelines are presented below in this document in table format.

Temperature:

Temperature for aquatic biota is not always set as an absolute. However, note must be made that most of the native fish species are adapted to colder water temperatures. Ideally temperatures should not exceed >30°C although some hardy species may endure 40°C. Ideally for the fish species studied during this study, temperatures varying between 14°C and 24°C are preferable. Colder temperatures may be endured by the native fish species. The 24°C temperature range is often considered an ideal temperature for fish breeding and sustainability.

Present state rating values for temperature

Rating	Deviation from reference condition	Environmental clues about the temperature status	Deviation from the natural monthly temperature range (10^{th} & 90^{th} percentile values)
0	No change	Pristine river, catchment natural, no known problems with temperature. All temperature sensitive species present in abundances and frequencies of occurrence as expected for reference.	Natural temperature range, measured or estimated from air temperature
1	Small change	Some minor man-made changes to the river but no known changes to the natural temperature regime. Some highly temperature sensitive species in lower abundance and frequency of occurrence than expected for reference.	Natural temperature range, measured or estimated from air temperature
2	Moderate change	Moderate change to temperature, occurs infrequently. Most highly temperature sensitive species in lower abundances and frequency of occurrence than expected for reference.	Vary by no more than 2°C
3	Large change	Large change to temperature regime occurs often. Most moderately temperature sensitive species in lower abundances and frequency of occurrence than expected for reference.	Vary by no more than 4°C
4	Serious change	Serious changes to temperature regime, occurs most of the time, only biota highly tolerant to temp changes occur. All moderately temperature sensitive species in much lower abundances and frequency of occurrence than expected for reference. Temperature insensitive species may have high abundances and frequency of occurrence.	Vary by more than 4°C
5	Extreme change	Extreme changes to temperature regime, occurs all the time, only biota highly tolerant to temp changes occur. At best, only temperature insensitive species present, often with very low abundances and frequency of occurrence.	Vary by more than 5°C, up to a maximum 30°C for the upper boundary

Electrical Conductivity

Present state rating values for salts using Electrical Conductivity (mS/m)

Natural – Poor categories	A – F category	Rating category	mS/m
Natural	A	0	≤ 30
Good	B	1	30.1 - ≤55
Upper Fair	C	2	55.1 - ≤85
Lower Fair	D	3	>85
Poor	E/F	4	-

pH

A neutral range of 7 to 7.5pH is preferable for fish and aquatic biota. Lower (6.5pH) to higher limits of 8.8pH are also acceptable.

Present state rating values for pH

Rating	Deviation from reference condition	pH (5^{th} percentile)	pH (95^{th} percentile)
0	No change	6.5 to 8.0	6.5 to 8.0
1	Small change	5.9 – 6.5	8.0 – 8.8
2	Moderate change	5.6 – 5.9	8.8 – 9.2
3	Large change	5.0 – 5.6	9.2 – 10.0
4	Serious change	4.0 - 5.0	10.0 – 11.0
5	Extreme change	<4	>11.0

Dissolved oxygen

A dissolved oxygen count of 8mg/L puts the environment in a good status. Small to moderate changes will give readings of >8mg/L and <5.9mg/L. Large changes will be 4-6mg/L and serious 2-4mg/L.

Present state rating values for dissolved oxygen

Rating	Deviation from reference condition	Environmental clues about the dissolved oxygen status	Dissolved oxygen concentration (mg/L)
0	No change	Known to be a pristine river, no known problems or concerns about dissolved oxygen; all oxygen sensitive species are present.	> 8
1	Small change	Some man-made modifications in the catchment but no known problems or concerns about DO, most oxygen sensitive species are present.	7 – 8
2	Moderate change	Some concerns about dissolved oxygen, some oxygen sensitive species are present but mostly oxygen tolerant species.	6 – 7
3	Large change	Known problems with reduced dissolve oxygen, mostly low DO tolerant species are present.	4 – 6
4	Serious change	Major know problems with low dissolved oxygen, anoxic odours sometimes present, only very low DO tolerant species present.	2 – 4

Rating	Deviation from reference condition	Environmental clues about the dissolved oxygen status	Dissolved oxygen concentration (mg/L)
5	Extreme change	Extreme concerns about low DO, anoxic odours present most of the time, colour of the water often dark with organic material, benthic algae replaced by grey/black bacterial films and sewage fungus, no biota present most of the time.	0 – 2

TABLE 12-1. PHYSICO-CHEMICAL TARGETS AND TPCS FOR A3KAAL-RIETS

SITE DATE CODE	TIME (24 hours)	DISCHARGE MEASURED CUMEC	TEMP	OXYGEN mg/l	pH	CONDUCTIVITY (mS/m)	TURBIDITY TUBE cm	TURBIDITY RATING	COLOUR	ODOUR	WATER COLUMN ALGAE
2015/03/02	0.6	-	21.1	8.6	7.9	25.8	0.0	0.0	0.0	0.0	0.0
TPC EXCEEDED			+	+	+	+		+	+	+	+
TARGET EXCEEDED			+	+	+	+		+	+	+	+
TPC UPPER LIMIT			25.0		8.5	35.0					
TPC LOWER LIMIT		0.3		8.0	7.0						
TARGET		0.3	24.0	8.5	7.5	30.0	0.0	0.0	0.0	0.0	0.0

Three fish species at this site are intolerant to water quality changes. All measured parameters occur within and were set within acceptable boundaries for the intolerant fish species present (see info above). Therefore, the habitat and water quality conditions will also be sufficient for the other fish species present at this site.

TABLE 12-2. TOLERANCE: MODIFIED PHYSICO-CHEM (EXTRACTED FROM THE FRAIS FOR A3KAAL-RIETS)

SPECIES EXPECTED: REFERENCE (NOT INTRODUCED SPP)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
AMOS	0.00	0.00	2.50	0.00
AURA	4.80	0.00	0.00	0.00
BBRI	4.10	0.00	0.00	0.00
BMAR	0.00	0.00	2.10	0.00
BMAT	0.00	3.20	0.00	0.00
BMOT	0.00	3.10	0.00	0.00
BPAU	0.00	0.00	0.00	1.80
BPOL	0.00	0.00	2.90	0.00
BTRI	0.00	0.00	0.00	1.80
BUNI	0.00	0.00	2.20	0.00
CGAR	0.00	0.00	0.00	1.00
CPRE	4.50	0.00	0.00	0.00
LCYL	0.00	3.10	0.00	0.00
LMOL	0.00	3.20	0.00	0.00
MBRE	0.00	0.00	2.80	0.00

OMOS	0.00	0.00	0.00	1.30
PPHI	0.00	0.00	0.00	1.40
TSPA	0.00	0.00	0.00	1.40

Ecostatus

The Ecostatus for site A3KAAL-RIETS was set at 83% (B category), with a corresponding TPC of 85%. The target is not met in April 2013 with the TPC never being met during the five sampling events (Table 12-3).

The DSS (Figure 12-1) needs to be implemented in order to determine possible causes for the Ecostatus TPCs not being met. It appears that the reason for the Ecostatus TPCs not being met are due to the riparian vegetation targets and TPCs never met for the entire study period. Decisions will need to be made by management to either refine the targets and TPCs or to take management action to improve the riparian vegetation integrity.

TABLE 12-3. SITE ECOSTATUS

SITE ECOSTATUS	FISH			MACRO-INVERTEBRATES			INSTREAM ECOLOGICAL CATEGORY (EC)				
DATE CODE	FISH ECOLOGICAL CATEGORY (FRAI)%: TARGET & SURVEY	FISH ECOLOGICAL CATEGORY: TARGET & FOR SURVEY	FISH ECOLOGICAL CATEGORY (FRAI)%: TPC & SURVEY	INVERTEBRATE ECOLOGICAL CATEGORY (MIRAI)% REC (TARGET) & PRESENT	INVERTEBRATE ECOLOGICAL CATEGORY	INVERTEBRATE ECOLOGICAL CATEGORY (MIRAI)% TPC & SURVEY	WEIGHED INSTREAM ECOLOGICAL CATEGORY % REC (TARGET) & SURVEY	INSTREAM ECOLOGICAL CATEGORY (REC (TARGET) & SURVEY	INSTREAM ECOLOGICAL CATEGORY: TPC	VEGRAI: RIPARIAN VEGETATION ECOLOGICAL CATEGORY%: TARGET & SURVEY	VEG
	93.0	A	94.0	83.0	B	85.0	82.0	C/B	83.0	85.0	B
2013/04/17-SITE-POOL-RUN-RIFFLE-RAPID	89.5	A/B	89.5	85.9	B	85.9	87.3	B	87.3	77.7	C
2013/08/08-SITE-POOL-RUN-RIFFLE-RAPID	97.5	A	97.5	87.8	B	87.8	91.7	A/B	91.7	77.7	C
2014/06/09-SITE-POOL-RUN-RIFFLE-RAPID	96.2	A	96.2	86.8	B	86.8	90.6	A/B	90.6	77.7	C
2014/09/15-SITE-POOL-RUN-RIFFLE-RAPID	96.4	A	96.4	86.8	B	86.8	90.6	A/B	90.6	77.7	C
2015/03/02-SITE-POOL-RUN-RIFFLE-RAPID	93.1	A	93.1	86.8	B	86.8	89.3	A/B	89.3	77.7	C

12.4.2 A3 GMAR-KOEDO

This site was assessed on five different occasions from 2013 – 2015. One cross-section was assessed in the riffle GHU.

FIGURE 12-7. CROSS SECTION IN THE RUN GHU, A3GMAR - KOEDO

Instream and riparian IHI

The site-based IHI can be used to indicate change over a period of time. For this site, the IHI remained constant, with very little change taking place over the duration of the project and thus the site IHI remained unchanged.

For the instream IHI, targets and TPCs were derived for the following components (Figure 12-8):

Water abstraction, bed modification, flow modification, and physico-chemical modification.

These components were considered important for this site, in terms of potential modification due to land-use in the adjacent and upper catchment.

The instream IHI Target was set at 85% and the TPC was set at 82%, thus a B instream IHI ecological category was set as the target for this site. The IHI category was determined as a B/C at 78.5%, lower than the recommended targets and TPCs.

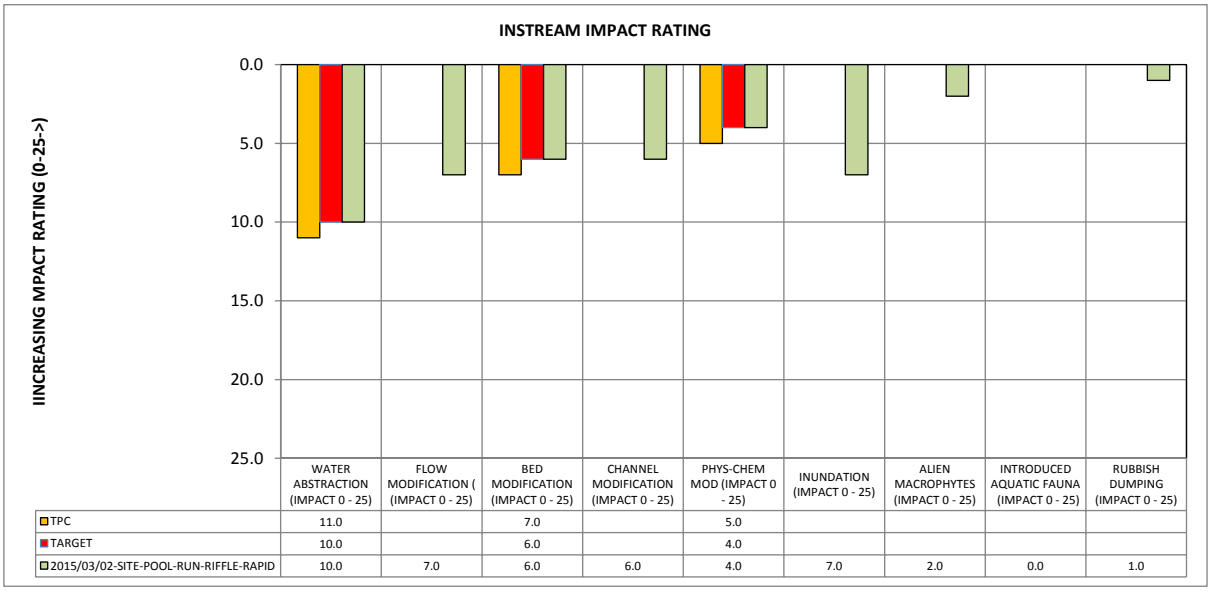


FIGURE 12-8. INSTREAM TARGETS & TPCS FOR SELECTED PHYSICO-CHEMICAL INSTREAM IHI COMPONENTS

For the riparian IHI, targets and TPCs were derived for the following components:

Exotic vegetation only (Figure 12-9). This component of the riparian vegetation was considered important for this specific site in terms of the land-use and potential impacts at the site. Exotic vegetation on the right bank is prominent and diverse and thus considered a serious impact to the riparian vegetation at this site.

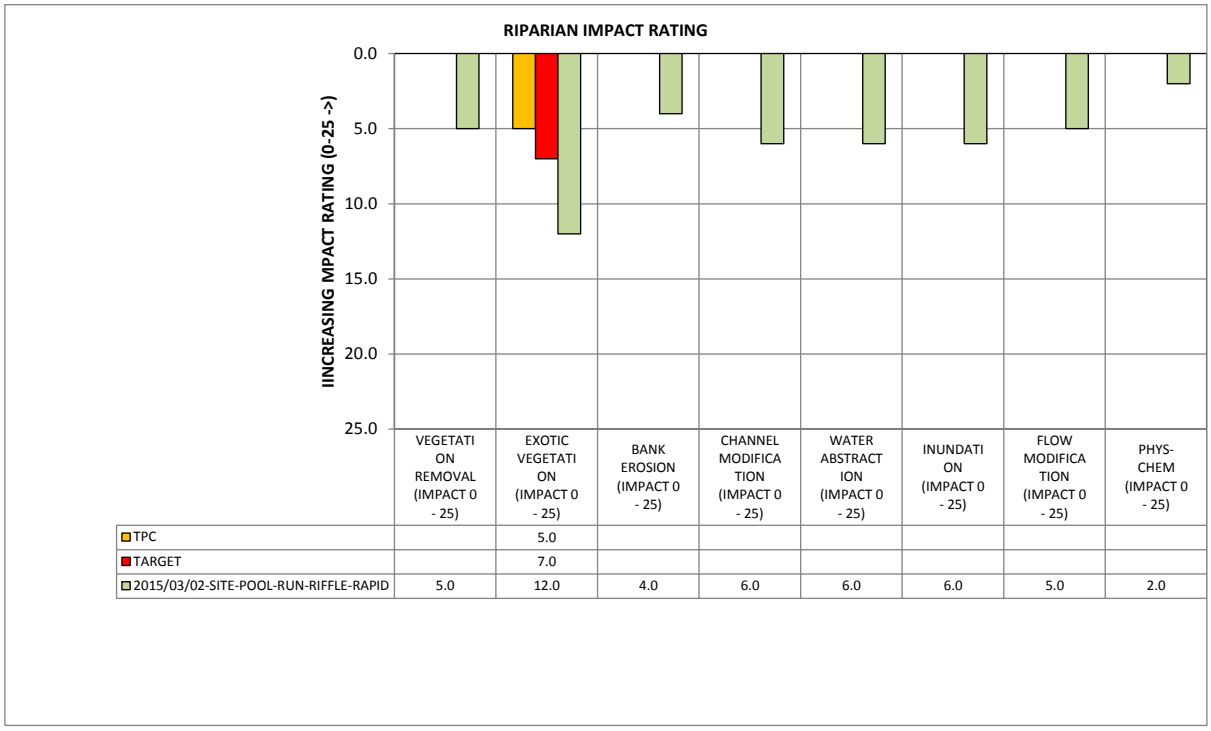


FIGURE 12-9. RIPARIAN TARGETS & TPCS FOR SELECTED RIPARIAN IHI COMPONENTS

The riparian IHI EC was determined as a C category at 69.8%, with a target set at 85% (B category) and a TPC set at 82%. The targets and TPCs were never met for the riparian vegetation IHI, according to the TARG/TPC/REP sheet which summarises the targets and TPCs over the total assessments and indicates which of the targets and TPCs are met or not met per component.

Fish

Sixteen fish species are expected under reference conditions for this site, with a minimum of two species sampled in September 2014 and a maximum of three species sampled in April 2013, June 2014 and March 2015 respectively. The fish EC for the project duration varied from 82.4% (B category) in March 2015 to 82.9% (B category) for the rest of the sampling events. The FRAI target was set at 82.5% (B category) with the related TPC set at 83.5%. The FRAI target was not met in March 2015, with none of the TPCs being met throughout the project (RHAM sheet TARG/TPC/REP).

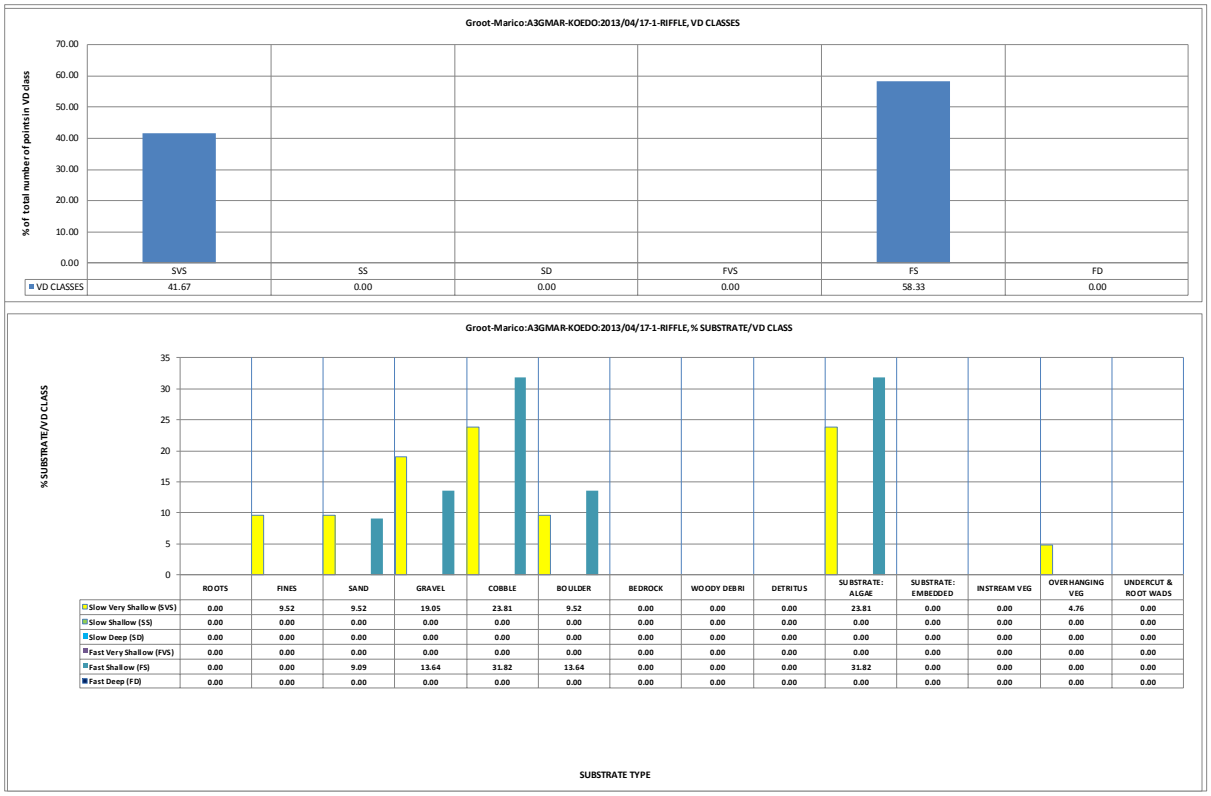


FIGURE 12-10. PERCENTAGE OF TOTAL NUMBER OF POINTS IN VELOCITY-DEPTH CLASSES (TOP GRAPH) AND % SUBSTRATE PRESENT PER VELOCITY-DEPTH CLASS (BOTTOM GRAPH) FOR 2013/04/17

In April 2013, the velocity-depth habitat in the riffle GHU was dominated by the fast shallow velocity-depth class (58.33%), followed by the slow very shallow class at 41.67%. These were the only two velocity-depth classes at the site at this time (Figure 12-10). Cobble gravel, boulder, sand and fines were present, with limited overhanging vegetation present. Algae (diatoms) were also present in the SVS and FS velocity-depth classes.

Macroinvertebrates

Macroinvertebrates were sampled in all available RHAM habitats, namely that of pool, run, riffle and rapids during five different sampling events between 2013 – 2015. The MIRAI EC for all sampling events is a category A/B, varying from 88.1% - 88.9%, with the MIRAI target set at 88.1% (A/B category) and the TPC set at 89%. The EC target is met at all times, with the TPC not met during all five sampling events (TARG/TPC/REP sheet). The minimum SASS total score target was set at 180 and the TPC set at 185, while the minimum ASPT target was set at 6.3 and the ASPT TPC was set at 6.4. Indicator taxa selected for the site include Coenagrionidae, Gomphidae, Heptageniidae, Perlidae and Tricorythidae. These taxa are considered representative of available biotopes at the site, as well as generally present in fair abundances and fairly sensitive to flow and water quality conditions to varying degrees. Most of the indicator taxa are present during all sampling events, except for Perlidae in April 2013 and Coenagriondiae in June 2014.

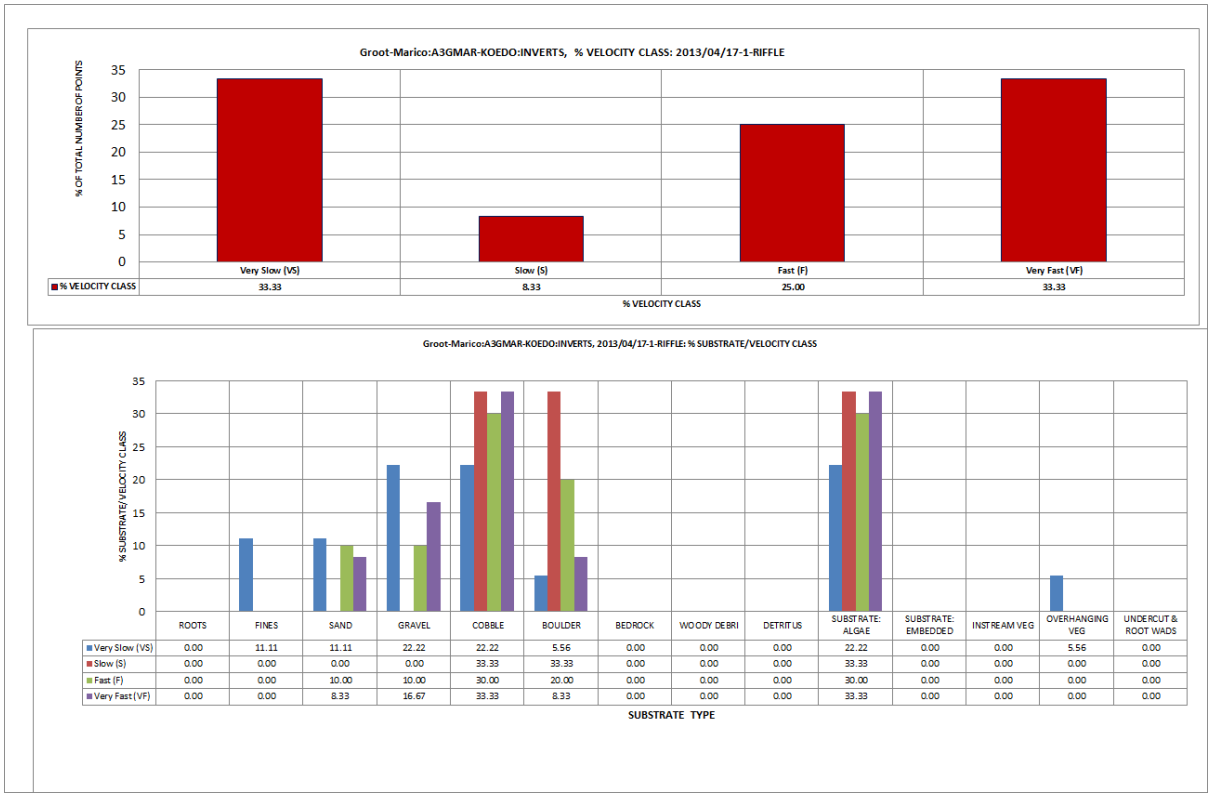


FIGURE 12-11. VELOCITY-DEPTH CLASSES AS A % OF ALL CROSS-SECTION POINTS (TOP GRAPH) AND % SUBSTRATE PRESENT PER VELOCITY-DEPTH CLASS (BOTTOM GRAPH), FOR MACROINVERTEBRATES AS AT 17 APRIL 2013

The very slow and very fast velocity classes are dominant at 33.33%, followed by fast at 25% and slow at 8.33%. The cobble substrate is dominant at the cross section, followed by the boulder, gravel, sand and fine substrate. No instream vegetation or bedrock is present, with some overhanging vegetation present (5.56% in the VS class).

Riparian vegetation

The riparian vegetation was assessed annually, with three different assessments conducted between 2013 – 2015. The VEGRAI for all three assessments varies from 61.71% (C/D category) in April 2013 and for the right bank in June 2014 to 55.68% (D category) in March 2015). The target was set at 82% (B category) and the corresponding TPC set at 85%. This means that none of the targets or TPCs are met during any of the assessments (TARG/TPC/REP).

Physico-chemical

Targets and TPCs were set, using fish species requirements for the relevant physic-chemical parameter. Reference is made to the following: Department of Water Affairs and Forestry, 2008. Methods for determining the Water Quality component of the Ecological Reserve. Guidelines from the publication were used to set the targets and TPCs. The guidelines are presented below in this document in table format.

Temperature:

Temperature for aquatic biota is not always set as an absolute. However, note must be made that most of the native fish species are adapted to colder water temperatures. Ideally temperatures should not exceed >30°C although some hardy species may endure 40°C. Ideally for the fish species studied during this study, temperatures varying between 14°C and 24°C are preferable. Colder temperatures may be endured by the native fish species. The 24°C temperature range is often considered an ideal temperature for fish breeding and sustainability.

Present state rating values for temperature

Rating	Deviation from reference condition	Environmental clues about the temperature status	Deviation from the natural monthly temperature range (10^{th} & 90^{th} percentile values)
0	No change	Pristine river, catchment natural, no known problems with temperature. All temperature sensitive species present in abundances and frequencies of occurrence as expected for reference.	Natural temperature range, measured or estimated from air temperature
1	Small change	Some minor man-made changes to the river but no known changes to the natural temperature regime. Some highly temperature sensitive species in lower abundance and frequency of occurrence than expected for reference.	Natural temperature range, measured or estimated from air temperature
2	Moderate change	Moderate change to temperature, occurs infrequently. Most highly temperature sensitive species in lower abundances and frequency of occurrence than expected for reference.	Vary by no more than 2°C
3	Large change	Large change to temperature regime occurs often. Most moderately temperature sensitive species in lower abundances and frequency of occurrence than expected for reference.	Vary by no more than 4°C
4	Serious change	Serious changes to temperature regime, occurs most of the time, only biota highly tolerant to temp changes occur. All moderately temperature sensitive species in much lower abundances and frequency of occurrence than expected for reference. Temperature insensitive species may have high abundances and frequency of occurrence.	Vary by more than 4°C
5	Extreme change	Extreme changes to temperature regime, occurs all the time, only biota highly tolerant to temp changes occur. At best, only temperature insensitive species present, often with very low abundances and frequency of occurrence.	Vary by more than 5°C, up to a maximum 30°C for the upper boundary

Electrical Conductivity

Present state rating values for salts using Electrical Conductivity (mS/m)

Natural – Poor categories	A – F category	Rating category	mS/m
Natural	A	0	≤ 30
Good	B	1	30.1 - ≤55
Upper Fair	C	2	55.1 - ≤85
Lower Fair	D	3	>85
Poor	E/F	4	-

pH

A neutral range of 7 to 7.5pH is preferable for fish and aquatic biota. Lower (6.5pH) to higher limits of 8.8pH are also acceptable.

Present state rating values for pH

Rating	Deviation from reference condition	pH (5^{th} percentile)	pH (95^{th} percentile)
0	No change	6.5 to 8.0	6.5 to 8.0
1	Small change	5.9 – 6.5	8.0 – 8.8
2	Moderate change	5.6 – 5.9	8.8 – 9.2
3	Large change	5.0 – 5.6	9.2 – 10.0
4	Serious change	4.0 - 5.0	10.0 – 11.0
5	Extreme change	<4	>11.0

Dissolved oxygen

A dissolved oxygen count of 8mg/L puts the environment in a good status. Small to moderate changes will give readings of >8mg/L and <5.9mg/L. Large changes will be 4-6mg/L and serious 2-4mg/L.

Present state rating values for dissolved oxygen

Rating	Deviation from reference condition	Environmental clues about the dissolved oxygen status	Dissolved oxygen concentration (mg/L)
0	No change	Known to be a pristine river, no known problems or concerns about dissolved oxygen; all oxygen sensitive species are present.	> 8
1	Small change	Some man-made modifications in the catchment but no known problems or concerns about DO, most oxygen sensitive species are present.	7 – 8
2	Moderate change	Some concerns about dissolved oxygen, some oxygen sensitive species are present but mostly oxygen tolerant species.	6 – 7
3	Large change	Known problems with reduced dissolve oxygen, mostly low DO tolerant species are present.	4 – 6
4	Serious change	Major know problems with low dissolved oxygen, anoxic odours sometimes present, only very low DO tolerant species present.	2 – 4
5	Extreme change	Extreme concerns about low DO, anoxic odours present most of the time, colour of the water often dark with organic material, benthic algae replaced by grey/black bacterial films and sewage fungus, no biota present most of the time.	0 – 2

TABLE 12-4. PHYSICO-CHEMICAL TARGETS AND TPCS FOR A3GMAR-KOEDO

SITE DATE CODE	TIME (24 hours)	DISCHARGE MEASURED CUMEC	TEMP	OXYGEN mg/l	pH	CONDUCTIVITY (mS/m)	TURBIDITY TUBE cm	TURBIDITY RATING	COLOUR	ODOUR	WATER COLUMN ALGAE
2015/03/02	0.6	-	22.5	8.5	7.4	27.7	0.0	0.0	0.0	0.0	0.0
TPC EXCEEDED			+	+	+	+		+	+	+	+
TARGET EXCEEDED			+	+	+	+		+	+	+	+
TPC UPPER LIMIT			28.0		8.0	30.0					
TPC LOWER LIMIT				7.0	7.0						
TARGET			24.0	8.4	7.3	27.8					

Two fish species at this site are intolerant to water quality changes. All measured parameters fall and were set within acceptable boundaries for the intolerant fish species present (see info above). Therefore, the habitat and water quality conditions will also be sufficient for the other fish species present at this site.

TABLE 12-5. TOLERANCE: MODIFIED PHYSICO-CHEM (EXTRACTED FROM THE FRAIS FOR A3GMAR-KOEDO)

SPECIES EXPECTED: REFERENCE (NOT INTRODUCED SPP)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
AMOS	0.00	0.00	2.50	0.00
AURA	4.80	0.00	0.00	0.00
BMAR	0.00	0.00	2.10	0.00
BMAT	0.00	3.20	0.00	0.00
BMOT	0.00	3.10	0.00	0.00
BPAU	0.00	0.00	0.00	1.80
BPOL	0.00	0.00	2.90	0.00
BTRI	0.00	0.00	0.00	1.80
BUNI	0.00	0.00	2.20	0.00
CFLA	0.00	0.00	0.00	2.00
CGAR	0.00	0.00	0.00	1.00
CPRE	4.50	0.00	0.00	0.00
LCYL	0.00	3.10	0.00	0.00
LMOL	0.00	3.20	0.00	0.00
MBRE	0.00	0.00	2.80	0.00
OMOS	0.00	0.00	0.00	1.30
PPHI	0.00	0.00	0.00	1.40
TSPA	0.00	0.00	0.00	1.40

Ecostatus

The Ecostatus target for site A3GMAR-KOEDO was set at 88.1% (B category), with a corresponding TPC of 89%. The target is only met in August 2013 with the TPC never being met during the five sampling events (Table 12-6).

The DSS (Figure 12-1) needs to be implemented in order to determine possible causes for the Ecostatus targets and TPCs not being met. It appears that the reason for the Ecostatus targets and TPCs not being met are mainly due to the IHI and riparian vegetation targets and TPCs not being met. Decisions will need to be made by management to either refine the targets and TPCs or to take management action to improve the IHI and riparian vegetation integrity.

TABLE 12-6. SITE ECOSTATUS FOR A3GMAR-KOEDO

SITE ECOSTATUS	FISH			MACRO-INVERTEBRATES			INSTREAM ECOLOGICAL CATEGORY (EC)			RIPARIAN VEGETATION (USE RIPARIAN IHI IF VEGRAI NOT AVAILABLE)				ECOSTATUS		
DATE CODE	FISH ECOLOGICAL CATEGORY (FRAI)%: TARGET & SURVEY	FISH ECOLOGICAL CATEGORY: TARGET & FOR SURVEY	FISH ECOLOGICAL CATEGORY (FRAI)%: TPC & SURVEY	INVERTEBRATE ECOLOGICAL CATEGORY (MIRAI)% REC (TARGET) & PRESENT	INVERTEBRATE ECOLOGICAL CATEGORY	INVERTEBRATE ECOLOGICAL CATEGORY (MIRAI)% TPC & SURVEY	WEIGHED INSTREAM ECOLOGICAL CATEGORY % REC (TARGET) & SURVEY	INSTREAM ECOLOGICAL CATEGORY (REC (TARGET) & SURVEY	INSTREAM ECOLOGICAL CATEGORY: TPC	VEGRAI: RIPARIAN VEGETATION ECOLOGICAL CATEGORY%: TARGET & SURVEY	VEGRAI: RIPARIAN VEGETATION ECOLOGICAL CATEGORY	VEGRAI: RIPARIAN VEGETATION ECOLOGICAL CATEGORY%: TPC & SURVEY	Confidence rating for riparian vegetation zone information	ECOSTATUS CATEGORY % TARGET & SURVEY	TARGET ECOSTATUS CATEGORY	ECOSTATUS CATEGORY % & TPC & SURVEY
	82.5	B	83.5	88.1	A/B	89.0	88.1	A/B	89.0	85.0	B	82.0		88.1	A/B	89.0
2013/04/17-SITE-POOL-RUN-RIFFLE-RAPID	82.9	B	82.9	88.1	A/B	88.1	85.9	B	85.9	61.7	C/D	61.7	4.0	73.1	C	73.1
2013/08/09-SITE-POOL-RUN-RIFFLE-RAPID				88.1	A/B	88.1	88.1	A/B	88.1					88.1	A/B	88.1
2014/06/09-SITE-POOL-RUN-RIFFLE-RAPID	82.9	B	82.9	88.9	A/B	88.9	86.3	B	86.3	57.9	D	57.9	4.0	71.3	C	71.3
2014/09/15-SITE-POOL-RUN-RIFFLE-RAPID	82.9	B	82.9	88.9	A/B	88.9	86.3	B	86.3					86.3	B	86.3
2015/03/02-SITE-POOL-RUN-RIFFLE-RAPID	82.4	B	82.4	88.5	A/B	88.5	85.9	B	85.9	52.8	D	52.8	4.0	68.4	C	68.4

12.4.3 A2 HEXR-ROOIW

This site was assessed on four different occasions from 2013 – 2015. Two cross-sections were assessed in the run GHU, numbered 1.01 and 1.02 respectively.

FIGURE 12-12. CROSS SECTIONS 1.01 AND 1.02 AT A2 HEXR-ROOIW

Instream and riparian IHI

The site-based IHI can be used to indicate change over a period of time. For this site, the IHI remained constant, with very little change taking place over the duration of the project and thus the site IHI remained unchanged.

For the instream IHI, targets and TPCs were derived for the following components (Figure 12-13):

Water abstraction, bed modification, flow modification, and physico-chemical modification.

These components were considered important for this site, in terms of potential modification due to land-use in the adjacent and upper catchment.

The instream IHI target was set at 58% and the TPC was set at 60%, thus a C/D instream IHI ecological category was set as the target for this site. The IHI EC was determined as a D at 48.2%, far lower than the recommended targets and TPCs, therefore the increased targets and TPCs that are considered realistic for this site with appropriate management intervention.

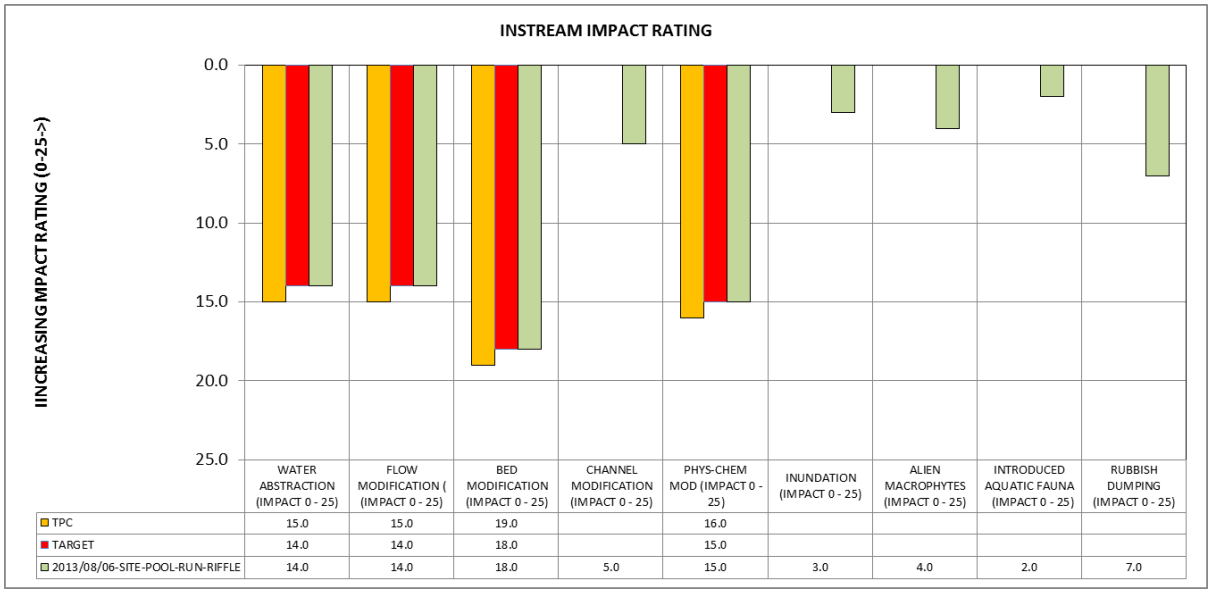


FIGURE 12-13. INSTREAM TARGETS & TPCS FOR SELECTED PHYSICO-CHEMICAL INSTREAM IHI COMPONENTS

For the riparian IHI, targets and TPCs were derived for the following components:

Vegetation removal, exotic vegetation and bank erosion (Figure 12-14). These components of the riparian vegetation were considered important for this specific site in terms of the land-use and potential impacts at the site.

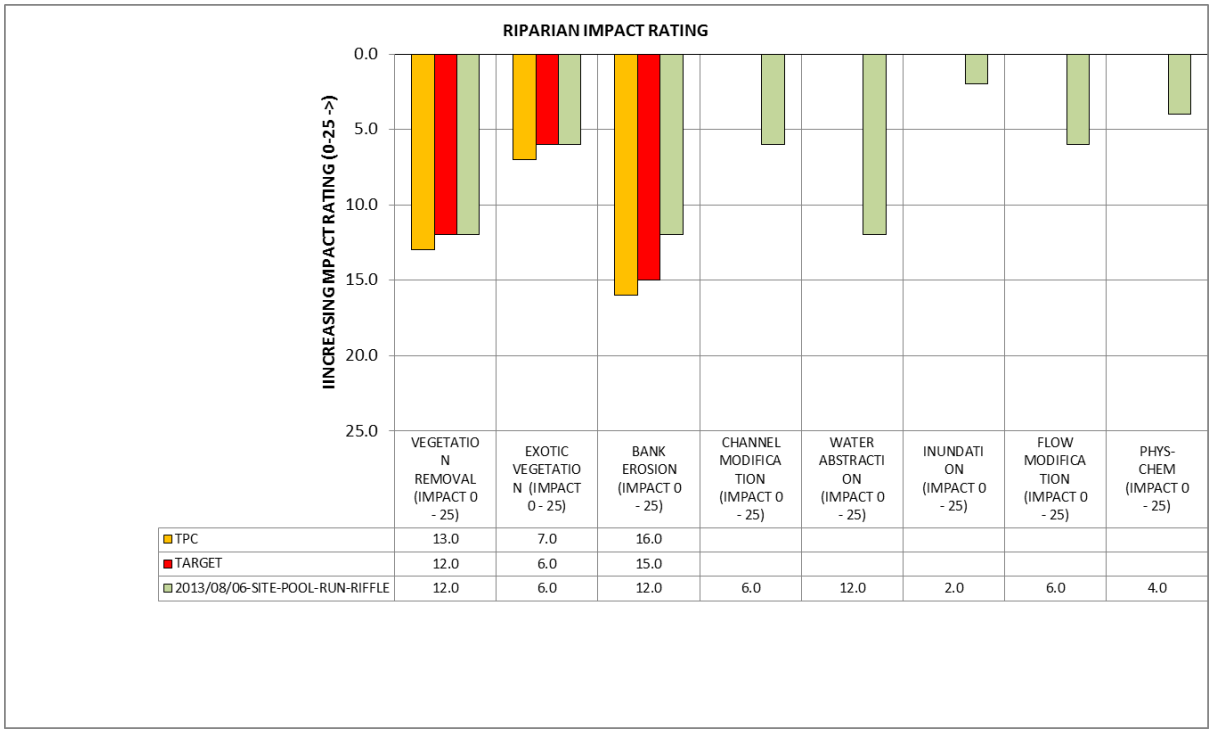


FIGURE 12-14. RIPARIAN TARGETS & TPCS FOR SELECTED RIPARIAN IHI COMPONENTS

The riparian IHI EC was determined as a D category at 46.9%, with a target set at 67% (C category) and a TPC set at 70%. The targets and TPCs were never met for the riparian vegetation IHI, according to the TARG/TPC/REP sheet which summarises the targets and TPCs over the total assessments and indicates which of the targets and TPCs are met or not met per component.

Fish

Twelve fish species are expected under reference conditions for this site, with a minimum of four species sampled in June 2014 and a maximum of five species sampled in September 2014 and March 2015 respectively. The fish EC for the project duration varied from 41.3% (D/E category) in September 2014 to 53.5% (D category) in June 2014. The FRAI target was set at 42.5% (D category) with the related TPC set at 44%. The FRAI target was not met in September 2014 and March 2015, with the TPC only met in June 2014 (RHAM sheet TARG/TPC/REP).

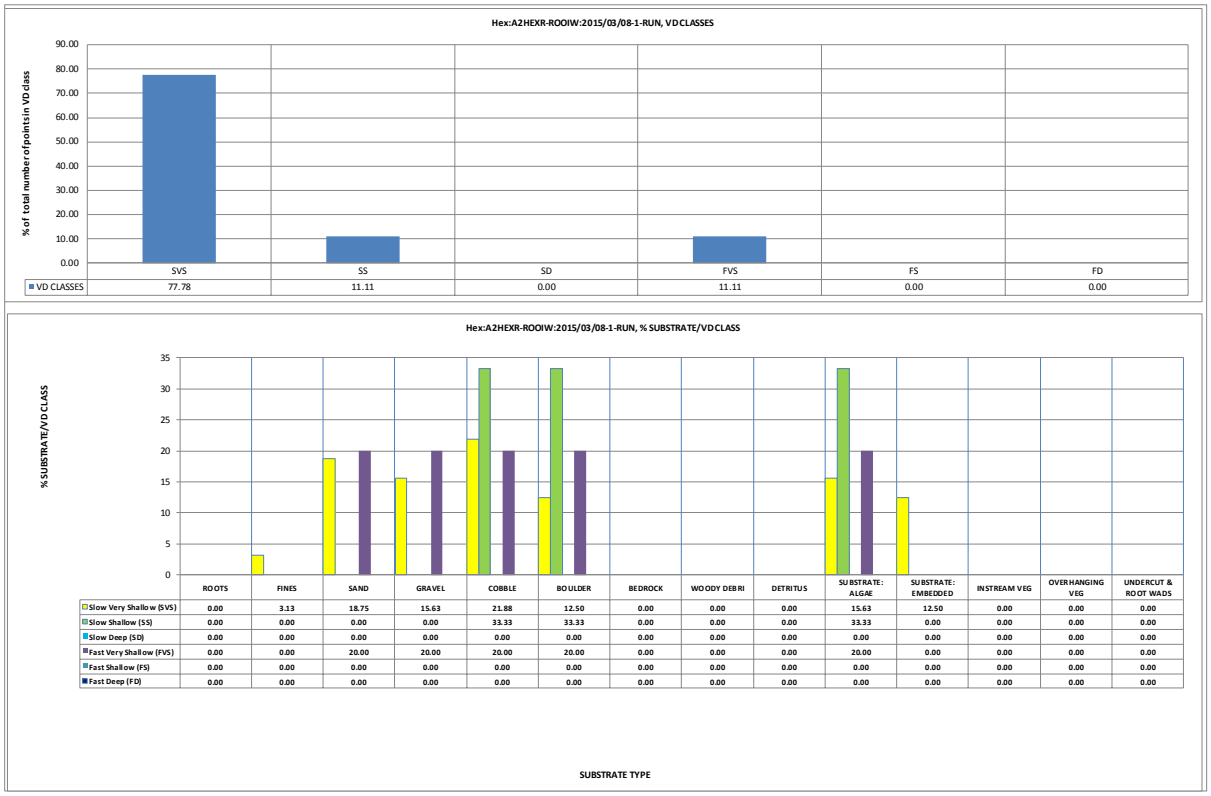


FIGURE 12-15. PERCENTAGE OF TOTAL NUMBER OF POINTS IN VELOCITY-DEPTH CLASSES (TOP GRAPH) AND % SUBSTRATE PRESENT PER VELOCITY-DEPTH CLASS (BOTTOM GRAPH) FOR 2015/03/08 IN THE RUN GHU

In March 2015, the velocity-depth habitat in the run GHU was dominated by the slow very shallor velocity-depth class (77.78%), followed by the slow shallow and fast very shallow classes at 11.11% each (Figure 12-15). Cobble, boulder, gravel, sand and fines were present, with filamentous algae present. Embedded substrate was present in the SVS class.

Macroinvertebrates

Macroinvertebrates were sampled in all available RHAM habitats, namely that of pool, run, riffle and rapids during four different sampling events between 2013 – 2015. The MIRAI EC for all sampling events is a category D, varying from 51.8% - 54.2%, with the MIRAI target set at 50% (D category) and the TPC set at 52%. The EC target is met at all times, with the TPC not met during June 2014 (TARG/TPC/REP sheet). The minimum SASS total score target was set at 60 and the TPC set at 65, while the minimum ASPT target was set at 4.4 and the ASPT TPC was set at 4.6. Indicator taxa selected for the site include Coenagrionidae, Gomphidae and 2spp. Hydropsychidae. These taxa are considered representative of available biotopes at the site, as well as generally present in fair abundances and fairly sensitive to flow and water quality conditions to varying degrees.

FIGURE 12-16. VELOCITY-DEPTH CLASSES AS A % OF ALL CROSS-SECTION POINTS (TOP GRAPH) AND % SUBSTRATE PRESENT PER VELOCITY-DEPTH CLASS (BOTTOM GRAPH), FOR MACROINVERTEBRATES AS AT MARCH 2015

The slow class dominates at 66.67%, followed by very slow at 22.22% and fast at 11.11%. The cobble substrate is dominant at the cross section, followed by the gravel, sand, boulder and fine substrates. No instream vegetation or bedrock is present. Algae is present, with embedded substrates present in the very slow and slow velocity-depth classes.

Riparian vegetation

The riparian vegetation was assessed annually, with two different assessments conducted between 2014 – 2015. The VEGRAI for these two assessments is determined as 61.21% (C/D category). The target was set at

67% (C category) and the corresponding TPC set at 70%. This means that none of the targets or TPCs are met during any of the assessments (TARG/TPC/REP).

Physico-chemical

Targets and TPCs were set, using fish species requirements for the relevant physic-chemical parameter. Reference is made to the following: Department of Water Affairs and Forestry, 2008. Methods for determining the Water Quality component of the Ecological Reserve. Guidelines from the publication were used to set the targets and TPCs. The guidelines are presented below in this document in table format.

Temperature:

Temperature for aquatic biota is not always set as an absolute. However, note must be made that most of the native fish species are adapted to colder water temperatures. Ideally temperatures should not exceed >30°C although some hardy species may endure 40°C. Ideally for the fish species studied during this study, temperatures varying between 14°C and 24°C are preferable. Colder temperatures may be endured by the native fish species. The 24°C temperature range is often considered an ideal temperature for fish breeding and sustainability.

Present state rating values for temperature

Rating	Deviation from reference condition	Environmental clues about the temperature status	Deviation from the natural monthly temperature range (10^{th} & 90^{th} percentile values)
0	No change	Pristine river, catchment natural, no known problems with temperature. All temperature sensitive species present in abundances and frequencies of occurrence as expected for reference.	Natural temperature range, measured or estimated from air temperature
1	Small change	Some minor man-made changes to the river but no known changes to the natural temperature regime. Some highly temperature sensitive species in lower abundance and frequency of occurrence than expected for reference.	Natural temperature range, measured or estimated from air temperature
2	Moderate change	Moderate change to temperature, occurs infrequently. Most highly temperature sensitive species in lower abundances and frequency of occurrence than expected for reference.	Vary by no more than 2°C
3	Large change	Large change to temperature regime occurs often. Most moderately temperature sensitive species in lower abundances and frequency of occurrence than expected for reference.	Vary by no more than 4°C
4	Serious change	Serious changes to temperature regime, occurs most of the time, only biota highly tolerant to temp changes occur. All moderately temperature sensitive species in much lower abundances and frequency of occurrence than expected for reference. Temperature insensitive species may have high abundances and frequency of occurrence.	Vary by more than 4°C
5	Extreme change	Extreme changes to temperature regime, occurs all the time, only biota highly tolerant to temp changes occur. At best, only temperature insensitive species present, often with very low abundances and frequency of occurrence.	Vary by more than 5°C, up to a maximum 30°C for the upper boundary

Electrical Conductivity

Present state rating values for salts using Electrical Conductivity (mS/m)

Natural – Poor categories	A – F category	Rating category	mS/m
Natural	A	0	≤ 30
Good	B	1	30.1 - ≤55
Upper Fair	C	2	55.1 - ≤85
Lower Fair	D	3	>85
Poor	E/F	4	-

pH

A neutral range of 7 to 7.5pH is preferable for fish and aquatic biota. Lower (6.5pH) to higher limits of 8.8pH are also acceptable.

Present state rating values for pH

Rating	Deviation from reference condition	pH (5^{th} percentile)	pH (95^{th} percentile)
0	No change	6.5 to 8.0	6.5 to 8.0
1	Small change	5.9 – 6.5	8.0 – 8.8
2	Moderate change	5.6 – 5.9	8.8 – 9.2
3	Large change	5.0 – 5.6	9.2 – 10.0
4	Serious change	4.0 - 5.0	10.0 – 11.0
5	Extreme change	<4	>11.0

Dissolved oxygen

A dissolved oxygen count of 8mg/L puts the environment in a good status. Small to moderate changes will give readings of >8mg/L and <5.9mg/L. Large changes will be 4-6mg/L and serious 2-4mg/L.

Present state rating values for dissolved oxygen

Rating	Deviation from reference condition	Environmental clues about the dissolved oxygen status	Dissolved oxygen concentration (mg/L)
0	No change	Known to be a pristine river, no known problems or concerns about dissolved oxygen; all oxygen sensitive species are present.	> 8
1	Small change	Some man-made modifications in the catchment but no known problems or concerns about DO, most oxygen sensitive species are present.	7 – 8
2	Moderate change	Some concerns about dissolved oxygen, some oxygen sensitive species are present but mostly oxygen tolerant species.	6 – 7
3	Large change	Known problems with reduced dissolve oxygen, mostly low DO tolerant species are present.	4 – 6
4	Serious change	Major know problems with low dissolved oxygen, anoxic odours sometimes present, only very low DO tolerant species present.	2 – 4
5	Extreme change	Extreme concerns about low DO, anoxic odours present most of the time, colour of the water often dark with organic material, benthic algae replaced by grey/black bacterial films and sewage fungus, no biota present most of the time.	0 – 2

TABLE 12-7. PHYSICO-CHEMICAL TARGETS AND TPCS FOR A2HEXR-ROOIW

SITE DATE CODE	TIME (24 hours)	DISCHARGE MEASURED CUMEC	TEMP	OXYGEN mg/l	pH	CONDUCTIVITY (mS/m)	TURBIDITY TUBE cm	TURBIDITY RATING	COLOUR	ODOUR	WATER COLUMN ALGAE
2015/03/08	0.5	0.1	25.5	7.8	8.3	120.1	0.0	0.0	1.0	0.0	1.0
TPC EXCEEDED		+	+	-	+	-		+	-	+	-
TARGET EXCEEDED		+	+	+	+	-		+	-	+	-
TPC UPPER LIMIT			28.0		8.4	65.0					
TPC LOWER LIMIT				70.0	7.0						
TARGET			25.5	7.7	7.5	45.0					

Most species are moderately to tolerant to water quality modification for this site. Two species are, however, moderately intolerant to water quality changes. The TPCs and targets set should, however, meet these fish species needs.

TABLE 12-8. TOLERANCE: MODIFIED PHYSICO-CHEM (EXTRACTED FROM THE FRAI'S FOR A2HEX-ROOIW)

SPECIES EXPECTED: REFERENCE (NOT INTRODUCED SPP)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
BMAR	0.00	0.00	2.10	0.00
BPAU	0.00	0.00	0.00	1.80
BTRI	0.00	0.00	0.00	1.80
BUNI	0.00	0.00	2.20	0.00
CFLA	0.00	0.00	0.00	2.00
CGAR	0.00	0.00	0.00	1.00
LCYL	0.00	3.10	0.00	0.00
LMOL	0.00	3.20	0.00	0.00
MBRE	0.00	0.00	2.80	0.00
OMOS	0.00	0.00	0.00	1.30
PPHI	0.00	0.00	0.00	1.40
TSPA	0.00	0.00	0.00	1.40

Ecostatus

The Ecostatus target for site A2HEXR-ROOIW was set at 58% (D category), with a corresponding TPC of 60%. The Ecostatus varies from 55.1% in September 2014 to 57.5 in June 2014, both category D. The target and TPC are never met (Table 12-9).

The DSS (Figure 12-1) needs to be implemented in order to determine possible causes for the Ecostatus targets and TPCs not being met. It appears that the reason for the Ecostatus targets and TPCs not being met are mainly due to the instream and riparian IHIs and riparian vegetation targets and TPCs not being met.

Decisions will need to be made by management to either refine the targets and TPCs or to take management action to improve the instream and riparian IHI and/or the riparian vegetation integrity.

TABLE 12-9. SITE ECOSTATUS FOR A2HEXR-ROOIW

SITE ECOSTATUS	FISH			MACRO-INVERTEBRATES			INSTREAM ECOLOGICAL CATEGORY (EC)			RIPARIAN VEGETATION (USE RIPARIAN IHI IF VEGRAI NOT AVAILABLE)				ECOSTATUS		
DATE CODE	FISH ECOLOGICAL CATEGORY (FRAI)%: TARGET & SURVEY	FISH ECOLOGICAL CATEGORY: TARGET & FOR SURVEY	FISH ECOLOGICAL CATEGORY (FRAI)%: TPC & SURVEY	INVERTEBRATE ECOLOGICAL CATEGORY (MIRAI)% REC (TARGET) & PRESENT	INVERTEBRATE ECOLOGICAL CATEGORY	INVERTEBRATE ECOLOGICAL CATEGORY (MIRAI)% TPC & SURVEY	WEIGHED INSTREAM ECOLOGICAL CATEGORY % REC (TARGET) & SURVEY	INSTREAM ECOLOGICAL CATEGORY (REC (TARGET) & SURVEY	INSTREAM ECOLOGICAL CATEGORY: TPC	VEGRAI: RIPARIAN VEGETATION ECOLOGICAL CATEGORY%: TARGET & SURVEY	VEGRAI: RIPARIAN VEGETATION ECOLOGICAL CATEGORY	VEGRAI: RIPARIAN VEGETATION ECOLOGICAL CATEGORY%: TPC & SURVEY	Confidence rating for riparian vegetation zone information	ECOSTATUS CATEGORY % TARGET & SURVEY	TARGET ECOSTATUS CATEGORY	ECOSTATUS CATEGORY % & TPC & SURVEY
	42.5	D	44.0	50.0	D	52.0	58.0	D	60.0	67.0	C	70.0		58.0	D	60.0
2013/08/06-SITE-POOL-RUN-RIFFLE	42.5	D	42.5	53.4	D	53.4	48.0	D	48.0	61.2	C/D	61.2	4.0	55.5	D	55.5
2014/06/14-SITE-POOL-RUN-RIFFLE-RAPID	53.5	D	53.5	51.8	D	51.8	52.7	D	52.7	61.2	C/D	61.2	4.0	57.5	D	57.5
2014/09/20-SITE-POOL-RUN-RIFFLE-RAPID	41.3	D/E	41.3	52.6	D	52.6	47.0	D	47.0	61.2	C/D	61.2	4.0	55.1	D	55.1
2015/03/08-SITE-POOL-RUN	41.4	D/E	41.4	54.2	D	54.2	47.8	D	47.8	61.2	C/D	61.2	4.0	55.5	D	55.5

12.4.4 A2 ELAN-KLIPB

This site was assessed on three different occasions from 2014 – 2015, with two RHAM measurements taken at a single cross-section in a run GHU.

FIGURE 12-17. CROSS-SECTION AT A2ELAN-KLIPB

Instream and riparian IHI

The site-based IHI can be used to indicate change over a period of time. For this site, the IHI remained constant, with very little change taking place over the duration of the project and thus the site IHI remained unchanged.

For the instream IHI, targets and TPCs were derived for the following components (Figure 12-18):

Water abstraction, bed modification and flow modification.

These components were considered important for this site, in terms of potential modification due to land-use in the adjacent and upper catchment.

The instream IHI target was set at 63% and the TPC was set at 65%, thus a C instream IHI ecological category was set as the target for this site. The IHI EC was determined as a C at 65.9%.

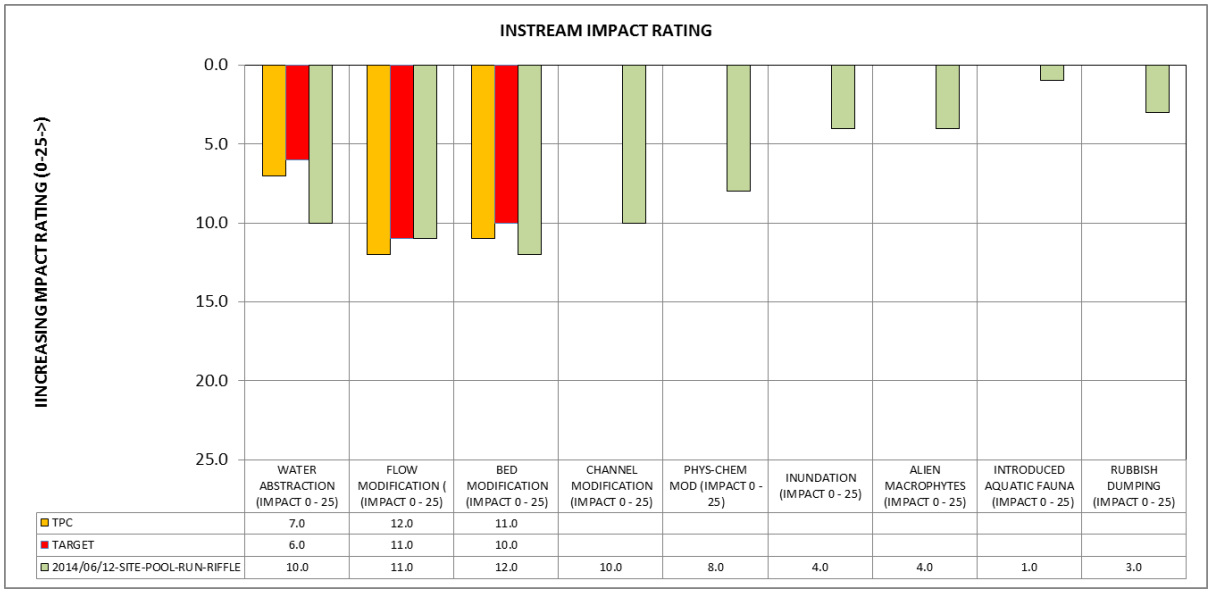


FIGURE 12-18. INSTREAM TARGETS & TPCS FOR SELECTED PHYSICO-CHEMICAL INSTREAM IHI COMPONENTS

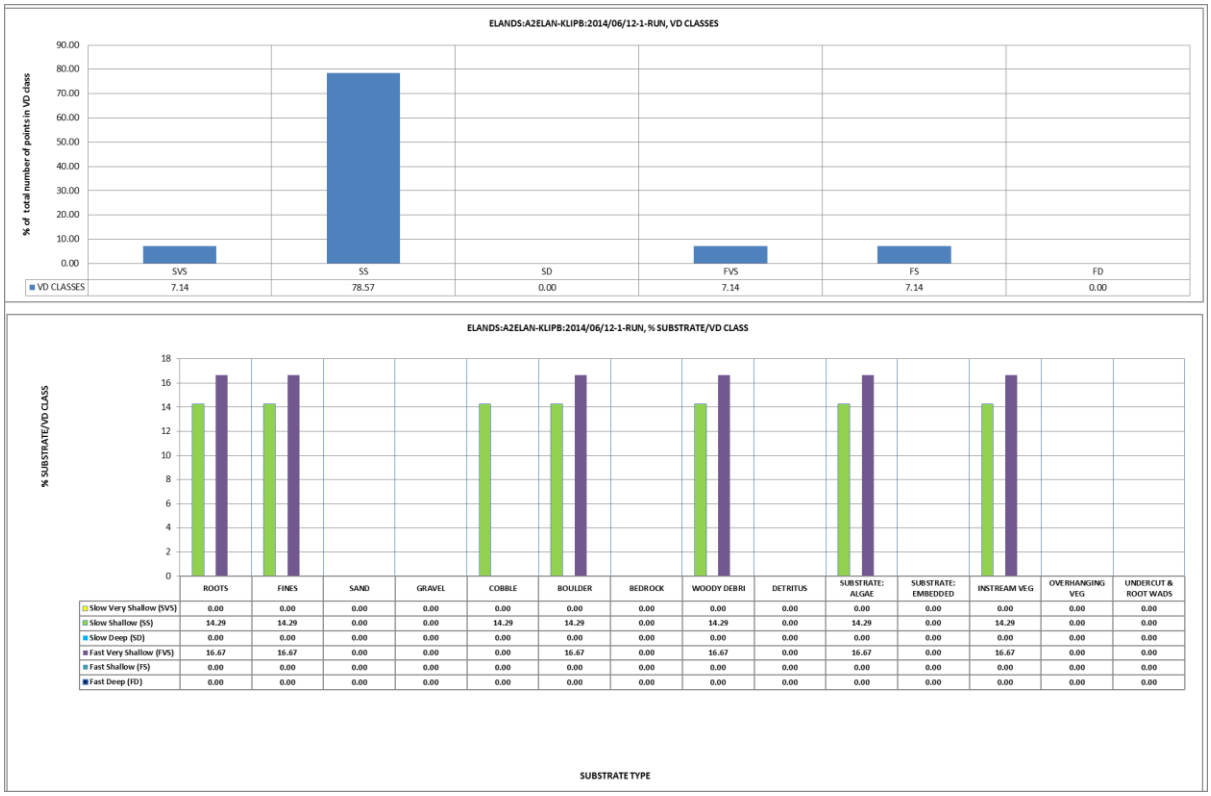
For the riparian IHI, targets and TPCs were derived for the following components:

Vegetation removal, exotic vegetation and bank erosion. These components of the riparian vegetation were considered important for this specific site in terms of the land-use and potential impacts at the site.

The riparian IHI EC was determined as a C/D category at 58%, with a target set at 63% (C category) and a TPC set at 65%. The targets and TPCs were never met for the riparian vegetation IHI, according to the TARG/TPC/REP sheet which summarises the targets and TPCs over the total assessments and indicates which of the targets and TPCs are met or not met per component.

Fish

Five fish species are expected under reference conditions for this site. The fish EC for the project duration varied from 76.9.3% (C category) in June 2014 to 50% (D category) in September 2014 and March 2015. The FRAI target was set at 55% (D category) with the related TPC set at 58%. The FRAI target and TPC was only met in June 2014 (RHAM sheet TARG/TPC/REP).



	ROOTS	FINES	SAND	GRAVEL	COBBLE	BOULDER	BEDROCK	WOODY DEBRI	DETRITUS	SUBSTRATE: ALGAE	SUBSTRATE: EMBEDDED	INSTREAM VEG	OVERHANGING VEG	UNDERCUT & ROOT WADS
Slow Very Shallow (SVS)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slow Shallow (SS)	14.29	14.29	0.00	0.00	14.29	14.29	0.00	14.29	0.00	14.29	0.00	14.29	0.00	0.00
Slow Deep (SD)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fast Very Shallow (FVS)	16.67	16.67	0.00	0.00	0.00	16.67	0.00	16.67	0.00	16.67	0.00	16.67	0.00	0.00
Fast Shallow (FS)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fast Deep (FD)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

FIGURE 12-19. PERCENTAGE OF TOTAL NUMBER OF POINTS IN VELOCITY-DEPTH CLASSES (TOP GRAPH) AND % SUBSTRATE PRESENT PER VELOCITY-DEPTH CLASS (BOTTOM GRAPH) FOR 2014/06/12 IN THE RUN GHU

In June 2014, the velocity-depth habitat in the run GHU was dominated by the slow shallow velocity-depth class (78.57%), followed by the slow very shallow, fast very shallow and fast shallow classes at 7.14% each (Figure 12-19). Cobble, boulder, roots, fines and woody debris were present. Filamentous algae and instream vegetation were also present.

Macroinvertebrates

Macroinvertebrates were sampled in all available RHAM habitats, namely that of pool, run and riffle during three different sampling events between 2014 – 2015. The MIRAI EC for all sampling events is a category C, varying from 73.1% - 73.9%, with the MIRAI target set at 70% (C category) and the TPC set at 72%. The EC target and TPC is met at all times (TARG/TPC/REP sheet). The minimum SASS total score target was set at 140 and the TPC set at 145, while the minimum ASPT target was set at 5.4 and the ASPT TPC was set at 5.5. Indicator taxa selected for the site include Coenagrionidae, Gomphidae and >2spp. Hydropsychidae. These taxa are considered representative of available biotopes at the site, as well as generally present in fair abundances and fairly sensitive to flow and water quality conditions to varying degrees.

FIGURE 12-20. VELOCITY-DEPTH CLASSES AS A % OF ALL CROSS-SECTION POINTS (TOP GRAPH) AND % SUBSTRATE PRESENT PER VELOCITY-DEPTH CLASS (BOTTOM GRAPH), FOR MACROINVERTEBRATES AS AT JUNE 2014

The slow class dominates at 78.57%, followed by very slow, fast and very fast at 7.14%. Roots, fines, cobble, boulder and woody debris substrates occur. Algae are present, as well as some instream vegetation.

Riparian vegetation

The riparian vegetation was assessed annually, with two different assessments conducted between 2014 – 2015. The VEGRAI for these two assessments varies between 64.29% (C category) in March 2015 to 69.64% (C category) on the right bank in June 2014. The target was set at 63% (C category) and the corresponding TPC set at 65%. This means that the TPCs are not met during any of the two assessments (TARG/TPC/REP).

Physico-chemical

Targets and TPCs were set, using fish species requirements for the relevant physic-chemical parameter. Reference is made to the following: Department of Water Affairs and Forestry, 2008. Methods for determining the Water Quality component of the Ecological Reserve. Guidelines from the publication were used to set the targets and TPCs. The guidelines are presented below in this document in table format.

Temperature:

Temperature for aquatic biota is not always set as an absolute. However, note must be made that most of the native fish species are adapted to colder water temperatures. Ideally temperatures should not exceed >30°C although some hardy species may endure 40°C. Ideally for the fish species studied during this study, temperatures varying between 14°C and 24°C are preferable. Colder temperatures may be endured by the native fish species. The 24°C temperature range is often considered an ideal temperature for fish breeding and sustainability.

Present state rating values for temperature

Rating	Deviation from reference condition	Environmental clues about the temperature status	Deviation from the natural monthly temperature range (10^{th} & 90^{th} percentile values)
0	No change	Pristine river, catchment natural, no known problems with temperature. All temperature sensitive species present in abundances and frequencies of occurrence as expected for reference.	Natural temperature range, measured or estimated from air temperature
1	Small change	Some minor man-made changes to the river but no known changes to the natural temperature regime. Some highly temperature sensitive species in lower abundance and frequency of occurrence than expected for reference.	Natural temperature range, measured or estimated from air temperature
2	Moderate change	Moderate change to temperature, occurs infrequently. Most highly temperature sensitive species in lower abundances and frequency of occurrence than expected for reference.	Vary by no more than 2°C
3	Large change	Large change to temperature regime occurs often. Most moderately temperature sensitive species in lower abundances and frequency of occurrence than expected for reference.	Vary by no more than 4°C
4	Serious change	Serious changes to temperature regime, occurs most of the time, only biota highly tolerant to temp changes occur. All moderately temperature sensitive species in much lower abundances and frequency of occurrence than expected for reference. Temperature insensitive species may have high abundances and frequency of occurrence.	Vary by more than 4°C
5	Extreme change	Extreme changes to temperature regime, occurs all the time, only biota highly tolerant to temp changes occur. At best, only temperature insensitive species present, often with very low abundances and frequency of occurrence.	Vary by more than 5°C, up to a maximum 30°C for the upper boundary

Electrical Conductivity

Present state rating values for salts using Electrical Conductivity (mS/m)

Natural – Poor categories	A – F category	Rating category	mS/m
Natural	A	0	≤ 30
Good	B	1	30.1 - ≤55
Upper Fair	C	2	55.1 - ≤85
Lower Fair	D	3	>85
Poor	E/F	4	-

pH

A neutral range of 7 to 7.5pH is preferable for fish and aquatic biota. Lower (6.5pH) to higher limits of 8.8pH are also acceptable.

Present state rating values for pH

Rating	Deviation from reference condition	pH (5^{th} percentile)	pH (95^{th} percentile)
0	No change	6.5 to 8.0	6.5 to 8.0
1	Small change	5.9 – 6.5	8.0 – 8.8
2	Moderate change	5.6 – 5.9	8.8 – 9.2
3	Large change	5.0 – 5.6	9.2 – 10.0
4	Serious change	4.0 - 5.0	10.0 – 11.0
5	Extreme change	<4	>11.0

Dissolved oxygen

A dissolved oxygen count of 8mg/L puts the environment in a good status. Small to moderate changes will give readings of >8mg/L and <5.9mg/L. Large changes will be 4-6mg/L and serious 2-4mg/L.

Present state rating values for dissolved oxygen

Rating	Deviation from reference condition	Environmental clues about the dissolved oxygen status	Dissolved oxygen concentration (mg/L)
0	No change	Known to be a pristine river, no known problems or concerns about dissolved oxygen; all oxygen sensitive species are present.	> 8
1	Small change	Some man-made modifications in the catchment but no known problems or concerns about DO, most oxygen sensitive species are present.	7 – 8
2	Moderate change	Some concerns about dissolved oxygen, some oxygen sensitive species are present but mostly oxygen tolerant species.	6 – 7
3	Large change	Known problems with reduced dissolve oxygen, mostly low DO tolerant species are present.	4 – 6
4	Serious change	Major know problems with low dissolved oxygen, anoxic odours sometimes present, only very low DO tolerant species present.	2 – 4
5	Extreme change	Extreme concerns about low DO, anoxic odours present most of the time, colour of the water often dark with organic material, benthic algae replaced by grey/black bacterial films and sewage fungus, no biota present most of the time.	0 – 2

TABLE 12-10. PHYSICO-CHEMICAL TARGETS AND TPCS FOR A2ELAN-KLIPB

SITE DATE CODE	TIME (24 hours)	DISCHARGE MEASURED CUMEC	TEMP	OXYGEN mg/l	pH	CONDUCTIVITY (mS/m)	TURBIDITY TUBE cm	TURBIDITY RATING	COLOUR	ODOUR	WATER COLUMN ALGAE
2014/06/12	0.6	0.3	8.9	10.2	6.7	7.3	-	1.0	0.0	0.0	1.0
TPC EXCEEDED		+	+	+	-	+		-	+	+	-
TARGET EXCEEDED		+	+	+	-	+		-	+	+	-
TPC UPPER LIMIT			27.0		8.0	12.0					
TPC LOWER LIMIT				7.0	6.9						
TARGET			25.0	7.1	7.5	10.0					

Four of the fish species expected are tolerant to modified water quality (table below), and one is moderately tolerant.

TABLE 12-11. TOLERANCE: MODIFIED PHYSICO-CHEM (EXTRACTED FROM THE FRAIS FOR A2ELAN-KLIPB)

SPECIES EXPECTED: REFERENCE (NOT INTRODUCED SPP)	INTOLERANT: MODIFIED WQ (>4)	MODERATELY INTOLERANT: MODIFIED WQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED WQ	TOLERANT: MODIFIED WQ (1-2)
CGAR	0.00	0.00	0.00	1.00
BMAR	0.00	0.00	2.10	0.00
BPAU	0.00	0.00	0.00	1.80
PPHI	0.00	0.00	0.00	1.40
TSPA	0.00	0.00	0.00	1.40

Ecostatus

The Ecostatus target for site A2ELAN-KLIPB was set at 70% (C category), with a corresponding TPC of 72%. The Ecostatus varies from 61.6% (category C/D) in September 2014 to 69.1% (category C) in June 2014. The target and TPC are only met in June 2014 (Table 12-12).

The DSS (Figure 12-1) needs to be implemented in order to determine possible causes for the Ecostatus targets and TPCs not being met. It appears that the reason for the Ecostatus targets and TPCs not being met are mainly due to the riparian IHIs and FRAI targets and TPCs not being met. Decisions will need to be made by management to either refine the targets and TPCs or to take management action to improve the riparian IHI and/or factors contributing to the fish integrity.

TABLE 12-12. SITE ECOSTATUS FOR A2ELAN-KLIPB

SITE ECOSTATUS	FISH			MACRO-INVERTEBRATES			INSTREAM ECOLOGICAL CATEGORY (EC)			RIPARIAN VEGETATION (USE RIPARIAN IHI IF VEGRAI NOT AVAILABLE)				ECOSTATUS		
DATE CODE	FISH ECOLOGICAL CATEGORY (FRAI)%: TARGET & SURVEY	FISH ECOLOGICAL CATEGORY: TARGET & FOR SURVEY	FISH ECOLOGICAL CATEGORY (FRAI)%: TPC & SURVEY	INVERTEBRATE ECOLOGICAL CATEGORY (MIRAI)% REC (TARGET) & PRESENT	INVERTEBRATE ECOLOGICAL CATEGORY	INVERTEBRATE ECOLOGICAL CATEGORY (MIRAI)% TPC & SURVEY	WEIGHED INSTREAM ECOLOGICAL CATEGORY % REC (TARGET) & SURVEY	INSTREAM ECOLOGICAL CATEGORY (REC (TARGET) & SURVEY	INSTREAM ECOLOGICAL CATEGORY: TPC	VEGRAI: RIPARIAN VEGETATION ECOLOGICAL CATEGORY%: TARGET & SURVEY	VEGRAI: RIPARIAN VEGETATION ECOLOGICAL CATEGORY	VEGRAI: RIPARIAN VEGETATION ECOLOGICAL CATEGORY%: TPC & SURVEY	Confidence rating for riparian vegetation zone information	ECOSTATUS CATEGORY % TARGET & SURVEY	TARGET ECOSTATUS CATEGORY	ECOSTATUS CATEGORY % & TPC & SURVEY
	55.0	D	58.0	70.0	C	72.0	70.0	C	72.0	63.0	C	65.0		70.0	C	72.0
2014/06/12-SITE-POOL-RUN-RIFFLE	76.9	C	76.9	73.1	C	73.1	75.0	C	75.0	64.6	C	64.6	4.0	69.1	C	69.1
2014/09/18-SITE-POOL-RUN-RIFFLE	50.0	D	50.0	73.1	C	73.1	61.6	C/D	61.6					61.6	C/D	61.6
2015/03/05-SITE-POOL-RUN	50.0	D	50.0	73.9	C	73.9	62.0	C/D	62.0	64.3	C	64.3	4.0	63.3	C	63.3

12.4.5 DISCUSSION

For site A3KAAL-RIETS, the FRAI targets and TPCs are not met in April 2013, as well as the TPC not met in March 2015. Riparian vegetation targets and TPCs are never met throughout the study period. The main reasons for the riparian vegetation targets and TPCs not being met include the increase in abundance of the alien invader species (*Acacia dealbata*), as well as overgrazing and trampling decreasing the integrity of the riparian vegetation on the right bank of this site. The integrated Ecostatus targets are mostly met except for April 2013. Integrated TPCs are never met at this site. Reasons would include the riparian vegetation TPCs which are influencing the overall Ecostatus at the site.

At site A3GMAR-KOEDO, throughout the study the instream IHI and riparian IHI targets and TPCs are never met. This seems to be due mainly to water abstraction impacting on the instream habitat and to the presence of exotic vegetation in the riparian zone at the site. Macroinvertebrate targets are always met, with fish targets not met in March 2015. Macroinvertebrate and fish TPCs are never met. Riparian vegetation targets and TPCs are never met at this site. This has an overall negative impact on the integrated Ecostatus targets, which are only met in August 2013.

At site A2HEXR-ROOIW, instream IHI and riparian IHI targets and TPCs are not met throughout the study. This is due mainly to physic-chemical modifications from upsteam landuse, including mining and urban impacts, as well as to bed modification from algal growth and increased sedimentation. Vegetation removal and bank erosion are two factors impacting the riparian vegetation negatively at this site. FRAI targets are met in August 2013 and June 2014 only, whilst MIRAI targets and TPCs met throughout, except for TPCs in June 2014. Instream Ecostatus and riparian vegetation targets and TPCs are never met, with the integrated targets and TPCs also never being met at this site.

At site A2ELAN-KLIPB, instream IHI targets and TPCs are always met. FRAI targets and TPCs are only met in June 2014, with the MIRAI targets and TPCs met throughout the three sampling events. Riparian vegetation targets are met; however the TPCs are not met. The integrated Ecostatus targets and TPCs are never met throughout the study. It would appear that the reasons for these targets and TPCs not being met are due to the fish integrity which is compromised at times (September 2014 and March 2015 for fish) and the riparian vegetation TPCs which are not met during June 2014 and March 2015.

It can be seen that throughout the study, not all targets and TPCs are always met at the different sites for the different components for various reasons. These targets and TPCs need to be continually assessed and revised and adjusted when necessary.

The DSS (Figure 12-1) needs to be consulted and implemented in order to make management decisions regarding a particular resource. Habitat and biological targets and TPCs derived from the RHAM will assist with decision-making. Continued monitoring at pre-determined intervals to derive relevant information to inform management should continue now that a baseline has been set for these systems.

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14 APPENDICES

See CD for specialist appendices.

SPECIALISTS APPENDICES

- Macroinvertebrates
- SASS Sheets
- Fish
- Riparian vegetation
- Diatoms
- RHAM
- RIVDINT